Ph.D
(Agricultural Engineering)

7. Ph.D Credit Requirements

The minimum credit requirements for Ph.D programme are as follows;

SL. NO.	COURSE WORK	CREDIT REQUIREMENTS
1.	Major Courses	12 Credits
2.	Minor Courses	06 Credits
3.	Supporting Courses	05 Credits
OTHER ESSENTIAL REQUIREMENTS		
1.	Doctoral Seminar I	0+1
2.	Doctoral Seminar II	0+1
3.	Doctoral Research	0+75

8. List of Ph.D Courses

8.1 Major Courses

8.1.1 Farm Machinery and Power Engineering

1. *FMPE 601 Advances in Farm Machinery and Power Engineering (2+1)
2. FMPE 602 Advances in Machinery for Precision Agriculture (2+1)
3. FMPE 603 Energy Conservation and Management in Production Agriculture (3+0)
4. FMPE 604 Mechanics of Tillage in Relation to Soil and Crop (2+1)
5. FMPE 611 Mechanics of Traction and its Application (2+1)
6. *FMPE 612 Farm Machinery Management and Systems Engineering (2+1)
7. FMPE 613 Machinery for Special Farm Operations (2+0)
8. FMPE 614 Ergonomics in Working Environment (2+1)

*Compulsory Courses

8.1.2. Processing and Food Engineering

1. *PFE 601 Advances in Food Process Engineering (2+1)
2. *PFE 602 Drying and Dehydration of Food Materials (2+1)
3. PFE 603 Textural and Rheological Characteristics of Food Materials (2+1)
4. PFE 604 Agricultural Waste and By Product Utilization (2+1)
5. PFE 605 Mathematical Modelling in Food Processing (3+0)
6. PFE 606 Bio Process Engineering (2+1)

*Compulsory Courses

8.1.3 Soil and Water Conservation Engineering

1. *SWCE 601 Advances in Hydrology (2+1)
2. *SWCE 602 Soil and Water Systems Simulation and Modelling (2+1)
3. SWCE 603 Reservoir Operation and River Basin Modelling (2+1)
4. SWCE 604 Modelling Soil Erosion Process and Sedimentation (2+1)
5. SWCE 605 Waste Water Treatment and Utilization (3+0)
6. SWCE 606 Hydro Chemical Modelling (2+0)

*Compulsory Courses

8.2 Minor Courses

8.2.1 Farm Machinery and Power Engineering

1. REE 602 Thermo-Chemical Conversion of Biomass (2+1)
2. REE 609 Energy Planning, Management and Economics (3+0)
3. ME 507 Fatigue Design (2+1)
4. ME 515 Computer Aided Design (2+1)
5. CSE 506 Digital Image Processing (2+1)

(Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.)

8.2.2 Processing and Food Engineering

1. REE 610 Renewable Energy for Industrial Applications (2+1)
2. CSE 506 Digital Image Processing (2+1)
3. ME 501 Mechatronics and Robotics in Agriculture (2+0)
4. CE 501 Dimensional Analysis and Similitude (2+0)

(Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.)

8.2.3 Soil and Water Conservation Engineering

1. IDE 601 Recent Developments in Irrigation Engineering (2+1)
2. IDE 602 Advances in Drainage Engineering (2+1)
3. IDE 603 Hydro-Mechanics and Groundwater Modelling (3+0)
4. IDE 604 Soil-Water-Plant-Atmospheric Modelling (2+1)
5. IDE 606 Multi Criteria Decision Making System (2+0)
6. CSE 503 Nuero Fuzzy Application in Engineering (2+1)
7. CSE 506 Digital Image Processing (2+1)

(Any other course(s) of other department other than course(s) from major can be taken as per recommendations of the student's advisory committee.)

8.3 Common supporting courses

1. *CPE-RPE Research Publication and Ethics (1+1)

Courses from subject matter fields (other than Major and Minor) relating to area of special interest and research problem can be taken as per recommendations of the student's advisory committee

*Course has been made compulsory by UGC for PhD students. Course code and its detailed course outline to be adopted in total as recommended by UGC.

8.4 Other essential requirements

8.4.1 Farm Machinery and Power Engineering

1. FMPE 691 Master's Seminar I (0+1)
2. FMPE 692 Master's Seminar II (0+1)
3. FMPE 699 Master's Research (0+75)

8.4.2 Processing and Food Engineering

1. PFE 691 Master's Seminar I (0+1)

2. PFE 692 Master's Seminar II (0+1)
3. PFE 699 Master's Research (0+75)

8.4.3 Soil and Water Conservation Engineering

1. SWCE 691 Master's Seminar I (0+1)
2. SWCE 692 Master's Seminar II (0+1)
3. SWCE 699 Master's Research (0+75)

9. Syllabus of Major Courses

9.1 Farm Machinery and Power Engineering

FMPE 601 ADVANCES IN FARM MACHINERY AND POWER ENGINEERING (2+1)

Aim

To familiarize the students about modern developments in construction, design and analysis of farm machinery systems as applied in different areas of agriculture

Theory

Unit I

Advances in mechanization as applicable to Indian context. Future outlook for improving agricultural productivity and reducing cost. Mechanization: Review of the applications of some of the advanced mechanization technologies and constraintsin adaptability. Levels of mechanization and transition between levels.

Unit II

Sustainable mechanization management: Management of compaction of agricultural fields. Strategies to develop machinery and systems that reduce compaction. Concept of Controlled Traffic Farming (CTF) systems. Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability

Unit III

Optimization of production processes to minimize energy loss in agriculture. The rationale for the use of photovoltaic systems in farming. The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.

Unit IV

Board sensors, computing hardware, algorithms and software. Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries.

Unit V

Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products. Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters. Silage process and their variants. Coordination of machinery system to enhance quality of silage and forage conditioners.

Practical

Case studies and presentations on: Mechanization in India-analysis of machinery data- mechanization index and relation between productivity and mechanization. Levels of mechanization in different crops. Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery. Planning use of multiple machinery-sugarcane harvesting system. Measurement of soil compaction due to heavy machinery using cone penetrometer. Machine vision system design–case studies. Challenges in development of robotic machinery in agricultural operations-case studies.

Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems, and managing crop productivity with poor quality of waters without deteriorating soil conditions

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Advances in mechanization as applicable to Indian context	2
2.	Mechanization in large scale agricultural fields	1
3.	Mechanization in small scale agricultural fields	1
4.	Future outlook for improving agricultural productivity and reducing cost.	1
5.	Requirements of energy and fuels for machinery operations	2
6.	Case studies of the applications of some of the advanced mechanization technologies and constraints in adaptability.	1
7.	Case studies of Technology transfer mechanisms in India	1
8.	Levels of mechanization and transition between levels.	1
9.	Sustainable mechanization management	1
10.	Management of compaction of agricultural fields	1
11.	Strategies to develop machinery and systems that reduce compaction	2
12.	Concept of Controlled Traffic Farming (CTF) systems.	1
13.	Introduction of wide span mechanization to vegetable production systems to enhance productivity and sustainability	2
14.	Optimization of production processes to minimize energy loss in agriculture	2
15.	The rationale for the use of photovoltaic systems in farming.	1
16.	The Energy Returned on Energy Invested (EROEI) ratio as an indicator for evaluating the efficiency of renewable energy sources.	2
17.	Machine vision system-hardware and software technologies, and machine learning and image analysis techniques	1
18.	Unmanned agricultural ground vehicles (UAGVs)	1
19.	UAGVs instrumented mobile platform, on board sensors, computing hardware, algorithms and software.	1
20.	Manipulator type ag-robots: Use in food processing, dairy, horticulture, and orchard industries	2
21.	Precision Livestock Farming (PLF): Individual identification and monitoring of animals, tractability of livestock products	1
22.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters	2
23.	Silage process and their variants. Coordination of machinery system enhance quality of silage and forage conditioners	1
24.	Silage and forage conditioners.	1
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Case studies of Mechanization in India	1
2.	Case studies of Mechanization in SAARC countries	1
3.	Numerical problems on determining mechanization index	1

4.	Relation between productivity and mechanization in India and Kerala.	1
5.	Relation between productivity and mechanization in developed countries.	1
6.	Levels of mechanization in cereal crops like paddy, Wheat etc.	1
7.	Levels of mechanization in Horticultural crops	1
8.	Levels of mechanization in cotton crop and pulses and oilseed crops	1
9.	Design of traffic lanes-field geometry and generating guideline lanes for operation of machinery.	1
10.	Planning use of multiple machinery-sugarcane harvesting system	1
11.	Measurement of soil compaction due to heavy machinery using cone penetrometer	1
12.	Machine vision system design - case studies	2
13.	Unmanned agricultural ground vehicles (UAGVs)for different applications like spraying, imaging and monitoring etc.	1
14.	Challenges in development of robotic machinery in agricultural operations-case studies.	1
15.	Developments in livestock and building control: Radio telemetry systems to remotely monitor and record physiological parameters	1
	Total	**16**

Suggested Reading

- Chen G. (ed). 2018. Advances in Agricultural Machinery and Technologies. Boca Raton: CRC Press, https://doi.org/10.1201/9781351132398
- Edwards GTC, Hinge G, Skou-Nielsen N and Villa-Henriksen A. 2017. Route Planning Evaluation of a Prototype Optimized in Field Route Planner for Neutral Material Flow Agricultural Operations. Biosystems Engineering 153: 149-157.
- https://www.sciencedirect.com/science/article/pii/S1537511016303713.
- Seyyedhasani H. 2017. Using the Vehicle Routing Problem (VRP) to Provide Logistic Solutions in Agriculture. Ph.D dissertation. University of Kentucky, Kentucky, USA. https://www.researchgate.net/publication/264791116_Advances in Agricultural Machinery Management A Review.
- Srivastava A K. 2006. Engineering Principles of Agricultural Machines. 2nd Edition American Society of Agricultural and Biological Engineers (ISBN) 1-892769-50-6 ASAE Publication 801M0206.

FMPE 602 ADVANCES IN MACHINERY FOR PRECISION AGRICULTURE (2+1)

Aim

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using

microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors

Unit III

Sources of soil variability, general soil sampling basics, systematic variability,selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non-imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management

Practical

Simple programming for automating precision farming calculations. Mathematicsof longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economicoptimum fertilizer and seeding rates cost of crop production.

Learning outcome

Ability to understand design and operate PA systems.

Lecture Schedule

Sl. No.	Topics	No. of Lectures
1.	Introduction about Global navigation satellite system (GNNS)	1
2.	Satellite ranging including accuracy, standards etc.	1
3.	Differential GNSS Receiver, RTK etc.	1
4.	Components of GIS, data layers, map component	1
5.	Attribute table component, function of a GIS, resolution.	1
6.	Data formats: Vector or raster	1
7.	GIS for precision farming, data analysis, field calculator, convert to grid Flood routing principles	1
8.	Interpolation, reclassification, image classification, band math and interpretation of analysis	1
9.	Farm management information systems, and crop intelligence.	1
10.	Introduction about Yield monitors and its components	1
11.	Mass flow and impact plate sensors, measuring volume with a photoelectric sensor	1
12.	Different types of grain moisture sensors	1
13.	Fan speed sensor, elevator speed sensor, header position, yield monitor data etc	1
14.	Yield monitors for non-grain crops	1
15.	Sources of soil variability, general soil sampling basics, systematic	1

variability

16.	Proximal and remote sensing-based soil sensors	1
17.	Electromagnetic based sensors for soil electrical conductivity Measurement	1
18.	Sensing mechanical impedance-based sensors for soil compaction	1
19.	Spectroscopy for determination of soil properties	1
20.	Introduction about proximal plant sensing systems	1
21.	Remote sensing platforms: Aircraft or satellite.	1
22.	Type of plant sensors: Imaging or non-imaging, active or passive.	1
23.	Use of reflected or emitted energy for vegetation detection	1
24.	The spectral signature of vegetation, vegetation indices, application to agriculture	1
25.	Sensing system for nutrient management,	1
26.	Crops canopy reflectance and fluorescence	1
27.	Machine vision thermal sensors, mechanical sensors, acoustic sensors	1
28.	Sensors for weed detection and management	1
29.	Sensing Techniques for disease and insect management,	1
30.	Different type of sensors/devices for water management.	1
	Total	**30**

List of Practicals

Sl. No.	**Topics**	**No. of Lectures**
1.	Simple programming for automating precision farming calculations	1
2.	Mathematics of longitude and latitude	1
3.	Spatial and temporal statistics using GIS	1
4.	Soil sampling strategies, understanding and results for precision farming	1
5.	Creation of management zones	1
6.	Measurement of yield variability in the field	1
7.	Measurement of soil Compaction in the field	1
8.	Measurement of soil EC in the field	1
9.	Measurement of soil pH in the field	1
10.	Developing and understanding prescriptive soil nutrient maps	1
11.	Measurement of essential plant nutrients in the field	1
12.	Fertilizer sources, and application rates calculations	1
13.	Deriving and using an equation to calculate economic optimum fertilizer	1
14.	Calculation of optimum seeding rates for optimized returns	1
15.	Cost of crop production using precision technologies	1
	Total	**15**

Suggested Reading

- Clay DE, Clay SA and Bruggeman SA. 2017. Practical Mathematics for Precision Farming. American Society of Agronomy, Madison, WI, USA
- Ram T, Lohan SK, Singh R and Singh P. 2014. Precision Farming: A New approach. Astral International Pvt. Ltd., New Delhi, India. ISBN: ISBN 978-81-7035-827-5 (Hardbound) ISBN 978-93-5130-258-2 (International Edition)

- Shannon DK, Clay DE and Kitchen NR Newell. 2018. Precision Agriculture Basics. American Society of Agronomy, Inc., Madison, WI, USA.
- Singh AK and Chopra UK. 2007. Geoinformatics Applications in Agriculture. New India Publishing Agency, New Delhi, India
- Van-Henten EJ, Goense D and Lokhorst C. (ed). 2009. Precision Agriculture. Wageningen Academic Publishers, Wageningen, Netherlands

FMPE 603 ENERGY CONSERVATION AND MANAGEMENT IN PRODUCTION AGRICULTURE (3+0)

Aim

Detailed study of the hardware system used in precision agriculture (PA) and techniques of using them in precision agriculture.

Theory

Unit I

Global navigation satellite system (GNNS). Satellite ranging: Accuracy, standards, components of GIS, data layers, map component, attribute table component, function of a GIS, resolution. Data formats: Vector or raster. GIS for precision farming, data analysis, field calculator, convert to grid, interpolation, reclassification, image classification, band math, interpretation of analysis, farm management information systems, and crop intelligence.

Unit II

Yield Monitors: Components, Differential GPS Receiver, GNSS Receiver, mass flow sensors. Impact plates, measuring volume with a photoelectric sensor. Using microwave radiation, and Gamma rays to estimate volume, volumetric flow sensing and alternatives. Grain moisture sensor, fan speed sensor, elevator speed sensor, header position, yield monitor data, cotton yield monitors.

Unit III

Sources of soil variability, general soil sampling basics, systematic variability, selecting a soil sampling strategy. Parameters: Electrical conductivity, electromagnetic sensors, sensing mechanical impedance. Proximal plant sensing systems, crops canopy reflectance and fluorescence. Machine vision thermal sensors, mechanical sensors, acoustic sensors.

Unit IV

Remote sensing platforms: Aircraft or satellite. Sensors: Imaging or non-imaging, active or passive. Making use of reflected energy or emitted energy. The spectral signature of vegetation, vegetation indices, application to agriculture, nutrient management, weed management, disease and insect management, water management.

Practical

Simple programming for automating precision farming calculations. Mathematics of longitude and latitude. Spatial statistics, soil sampling and understanding soil testing results for precision farming, calculations. Supporting management zones, understanding soil, water and yield variability in precision farming. Developing prescriptive soil nutrient maps, essential plant nutrients, fertilizer sources, and application rates calculations. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates cost of crop production.

Learning outcome

Ability to understand design and operate PA systems.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Introduction	1
2.	Classification of energy	2
3.	Energy coefficients	2
4.	Energy requirements for wheat production	2
5.	Energy requirements for paddy production	2
6.	Energy requirements for maize production	2
7.	Energy requirements for cotton production	2
8.	Energy requirements for oil seeds production	1
9.	Energy requirements for pulse production	2
10.	Energy requirements for production of other crops	2
11.	Energy requirements for vegetable production	2
12.	Energy requirements for fruit production	1
13.	Energy requirements for fish production	1
14.	Energy requirements for meat and milk production	2
15.	Limits of energy conservation	1
16.	Energy planning, management and forecasting in agriculture	3
17.	Design of integrated energy supply system	2
18.	Energy conservation and returns	2
19.	Assessment of energy conservation technology	2
20.	Case studies on application of various techniques of energy conservation and management	2
	Total	**36**

Suggested Reading

- Mittal JP, Panesar BS, Singh S, Singh CP and Mannan KD. 1987. Energy in Production Agriculture and Food Processing. ISAE and School of Energy Studies for Agriculture, PAU Ludhiana, ISAE Publication.
- Pimental D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press. Boca Rotan, USA.
- Singh S and Singh RS. 2014. Energy for Production Agriculture. DKMA, ICAR, New Delhi, India.

FMPE 604 MECHANICS OF TILLAGE IN RELATION TO SOIL AND CROP (2+1)

Aim

To have deeper understanding of the tillage process in terms of crop requirement, soil characteristics and machinery function.

Theory

Unit I

Soil condition and soil strength determining factors. General aspects of mechanical behavior of soil elements. Soil compaction, conditions for its occurrence. Methods of estimation of soil compaction by experimental stress distribution. Concept of soil distortion, deformation at constant volume. Expansion of soil at breaking.

Unit II

Occurrence of soil breaking fundamentals. Measures of resistance against breaking. Shear failure and Coulomb's law. Compaction v/s shear failure. Tensile failure of soil, idealized brittle failure, Griffith's Model. Loading rate and repeated loading effects. Draft calculation using mechanism of rigid soil bodies.

Unit III

Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening. Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage. Soil compaction, formation of clods and dust. Effect of tillage on erosion and water logging. Impact of climate factors on soil. Tillage requirement for various types of soils.

Unit IV

Tillage operations for special tasks. Preparation of soil for cropping and stubble management. Primary and secondary tillage. Ploughing and its effect on soil. Disc tillage: Appropriate conditions and effect. Requirement of seed bed and techniques of creating proper seed bed. Quality of sowing and sowing methods. Modern trends and objectives of soil tillage.

Unit V

Plough bodies: Generalized representation, intake main flow and output process. Main flow under different surface curvatures. Kinetic aspects of plough bodies with different shapes. Draft of plough bodies as affected by moisture, speed and attachments.

Practical

Characterization of soil condition before and after tillage. Cone penetrometer resistance, bulk density, moisture content. Measurement of forces on tillage tools under soil bin condition/ field condition. Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing. Measurement of energy required for soil breakup by different methods. Field study of crop root development in relation to soil compaction and hard pan. Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed. Field evaluation of plant establishment in relation to planting parameters.

Learning outcome

Ability to design tillage machinery based on engineering principles as applied tom tillage science.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Soil condition and soil strength determining factors.	1
2.	General aspects of mechanical behavior of soil elements.	1
3.	Soil compaction, conditions for its occurrence.	2
4.	Methods of estimation of soil compaction by experimental stress distribution	1
5.	Concept of soil distortion, deformation at constant volume.	1
6.	Expansion of soil at breaking.	1
7.	Occurrence of soil breaking fundamentals.	1
8.	Measures of resistance against breaking.	1
9.	Shear failure and Coulomb's law.	1
10.	Compaction v/s shear failure.	1
11.	Tensile failure of soil, idealized brittle failure, Griffith's Model.	1
12.	Loading rate and repeated loading effects.	1
13.	Draft calculation using mechanism of rigid soil bodies.	1
14.	Crop requirements: Root structure, Soil conditions and purpose of tillage, looseness of soil and depth of loosening.	1
15.	Structure of seed bed. Soil properties, properties affected by tillage and those not affected by tillage.	2
16.	Soil compaction, formation of clods and dust.	1

17.	Effect of tillage on erosion and water logging.	1
18.	Impact of climate factors on soil.	1
19.	Tillage requirement for various types of soils.	1
20.	Tillage operations for special tasks.	1
21.	Preparation of soil for cropping and stubble management.	1
22.	Primary and secondary tillage. Ploughing and its effect on soil.	1
23.	Disc tillage: Appropriate conditions and effect.	1
24.	Requirement of seed bed and techniques of creating proper seed bed.	1
25.	Quality of sowing and sowing methods.	1
26.	Modern trends and objectives of soil tillage.	1
27.	Plough bodies: Generalized representation, intake main flow and output process.	1
28.	Main flow under different surface curvatures.	1
29.	Kinetic aspects of plough bodies with different shapes.	1
30.	Draft of plough bodies as affected by moisture, speed and attachments.	1
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Characterization of soil condition before and after tillage.	2
2.	Cone penetrometer resistance, bulk density, moisture content.	1
3.	Measurement of forces on tillage tools under soil bin condition/ field ondition.	2
4.	Measurement of soil manipulation by different tillage tools: Pulverization, furrow profile, inversion and mixing.	2
5.	Measurement of energy required for soil breakup by different methods.	2
6.	Field study of crop root development in relation to soil compaction and hard pan.	2
7.	Measurement of moisture movement in different surface configuration: Ridges, furrows, raised bed and flat bed.	2
8.	Field evaluation of plant establishment in relation to planting parameters.	1
	Total	**14**

Suggested Reading

- Birkas M. 2014. Book of Soil Tillage. Szent Istvan University Press, Godollo, Hungary. ISBN-978-963-269-447-4 (Unit III & IV).
- Koolen AJ and Kuipers H. 1983. Agricultural Soil Mechanics. Springer-Verlag. New York, USA. ISBN 13:978-3-642-69012-9 (Unit I, II, V).

FMPE 611 MECHANICS OF TRACTION AND ITS APPLICATION (2+1)

Aim

Learning techniques of modelling soil traction device interaction under different states of wheel and under different soil conditions by analytical and empirical method.

Theory

Unit I

Tractor performance in soft soils, operational states of wheel: Wismer and Luth. Path traced by

point on tyre periphery. Rolling resistance, conditions of wheel soil interaction, theoretical prediction, work on soil deformation, Bekker's model, derivation of resistance offered by flat rigid plate on soft soil. Measurement of sinkage parameters. Soft wheel on soft surface and rigid wheel on soft surface. Empirical prediction of tractive force: Bekker's model, stress deformation relation in soil, analysis of tractive performance of tracks.

Unit II

Empirical modelling of tractor performance, tractive performance modelling and mobility number. Empirical models for rolling resistance and traction by Gee- Clough. Derivation of equations for drawbar pull and drawbar power.

Unit III

Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage. Rigid wheel at driving state: Ground reaction on rigid wheel during driving action, force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force. Energy equilibrium under driving wheel.

Unit IV

Wheel under braking state: Slip velocity and amount of slippage under braked wheel. Soil deformation under braked wheel. Distribution of shear stresses and normal stress under driving wheel.

Unit V

Tyre wheel system-deformation of tyre and area of contact. Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure. Ground reaction during pure rolling of tyre on hard surface. Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions. Relation between cornering force and self-aligning torque.

Practical

Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance. Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel. Measurement of performance of tyres under soil bin condition/field condition for driving and braking. Measurement of variation in contact patch of tractor tyres under different inflation pressures. Design of lugged wheels for wet puddle soil condition. Field performance of tractor.

Learning outcome

Ability to model vehicle traction mechanics and provide insight into behavior of vehicles under different soil conditions.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Tractor performance in soft soils, operational states of wheel: Wismer and Luth	3
2.	Path traced by point on tyre periphery.	4
3.	Rolling resistance, conditions of wheel-soil interaction, theoretical prediction, work on soil deformation, Bekker's Model, Derivation of resistance offered by flat rigid plate on soft soil.	2
4.	Measurement of sinkage parameters.	1
5.	Soft wheel on soft surface and rigid wheel on soft surface.	2
6.	Empirical prediction of tractive force: Bekker's model, stress deformation relation	2

	in soil, analysis of tractive performance of tracks	
7.	Empirical modelling of tractor performance, tractive performance modelling and mobility number	2
8.	Empirical models for rolling resistance and traction by Gee-Clough.	2
9.	Derivation of equations for drawbar pull and drawbar power.	2
10.	Rigid wheel systems. Rigid wheel at rest: Soil bearing capacity, contact pressure and sinkage.	1
11.	Rigid wheel at driving state: Ground reaction on rigid wheel during driving action.	1
12.	Force balance in soil reaction to driving wheel, determination of driving force, compaction resistance and effective driving force.	2
13.	Energy equilibrium under driving wheel.	2
14.	Wheel under braking state: Slip velocity and amount of slippage under braked wheel.	1
15.	Soil deformation under braked wheel.	1
16.	Distribution of shear stresses and normal stress under driving wheel.	1
17.	Tyre wheel system-deformation of tyre and area of contact.	1
18.	Deformation of tyre and its measurement. Tyre deformation as function of inflation pressure.	2
19.	Ground reaction during pure rolling of tyre on hard surface.	1
20.	Trafficability in soft terrain, concept of wheel mobility number-cornering characteristic of wheel forces on a steered wheel under driving and braking conditions.	2
21.	Relation between cornering force and self-aligning torque.	1
	Total	**36**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Measurement of soil parameters for modelling traction-simulation of the different traction models to obtain the tractive performance.	3
2.	Calculating the performance of tractor drive wheels, Braking performance of trailer wheels on road, Planter metering drive wheels, Tractor front wheel.	4
3.	Measurement of performance of tyres under soil bin condition/ field condition for driving and braking.	2
4.	Measurement of variation in contact patch of tractor tyres under different inflation pressures.	1
5.	Design of lugged wheels for wet puddle soil condition.	2
6.	Field experiment with tractive performance of tractor.	2
7.	Revision	1
8.	Revision	
	Total	**16**

Suggested Reading

- Muro T and O'Brien J. 2004. Terramechanics: Land Locomotion Mechanics. Lisse, Netherlands. ISBN 90 5809 572 X (Unit III, IV, V).
- Macmillan RH. 2010. The Mechanics of Tractor-Implement Performance: Theory and Worked Examples: A Textbook for Students and Engineers. Custom Book Centre, University of Melbourne, Australia. http://hdl.handle.net/11343/33718 (Unit I, II).

FMPE 612 FARM MACHINERY MANAGEMENT AND SYSTEMS ENGINEERING (2+1)

Aim

Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.

Theory

Unit I

Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains. Systems approach to field operations and models of: Tillage, seeding, chemical application, harvesting, storage and irrigation systems.

Unit II

Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money. Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.

Unit III

Uncertainty: Concepts of probability, probability functions, distributions, sampling. Statistics, confidence limits, significance, contingency tables, analysis of variance. Regression and correlation. Monte Carlo methods and applications to farm machinery.

Unit IV

System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system. Feasibility system design-stability. Deterministic systems and stochastic systems.

Unit V

Optimum Design: Trial and error, differential calculus, calculus of variations. Allocations: Linear programming, simplex technique. Transportation and assignment technique. Critical path scheduling, dynamic programming, game and its applications to farm machinery management.

Practical

Solving problems of mathematical models of field machinery, constraints, power constraints, weather constraints. Problems relates to tillage seeding chemical application harvesting and storage and irrigation systems. Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost. Case studies in machine performance modelling, Economics of machine selection, Analog components, Analog modelling stochastic system modelling and critical path scheduling.

Learning outcome

Ability to understand and develop model of any farm machinery system to help in selection, management and optimization.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Understanding Farm Machinery from systems approach and ability to model the Farm machinery system.	2
2.	Mathematical models of field machinery systems: Operational constrains, power constrains, weather constrains.	2
3.	Systems approach to field operations and models of: Tillage, seeding, chemical	3

	application, harvesting, storage and irrigation systems.	
4.	Engineering economics: Concept of incremental and differential cost, economic efficiency, time value of money	1
5.	Equipment investment cost: Operational cost, production cost, income cost and uncertainty cost. B.C. ratio, payback period, IRR machinery replacement policies.	2
6.	Uncertainty: Concepts of probability, probability functions, distributions, sampling	2
7.	Statistics, confidence limits, significance, contingency tables, analysis of variance.	1
8.	Regression and correlation. Monte Carlo methods and applications to farm machinery.	3
9.	System modeling in farm machinery: Numerical methods, analogs, models with uncertainty stochastic service system.	3
10.	Feasibility system design-stability	1
11.	Deterministic systems and stochastic systems.	2
12.	Optimum Design: Trial and error, differential calculus, calculus of variations	2
13.	Allocations: Linear programming, simplex technique Transportation and assignment technique	4
14.	Critical path scheduling, dynamic programming, game and its applications to farm machinery management.	4
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Problems solving of mathematical models of field machinery, constraints, power constraints, weather constraints	3
2.	Mathematical problems relate to tillage, seeding, chemical application harvesting and storage and irrigation systems	3
3.	Problem solving in Economics of Engineering, calculation of investment cost, operational cost, and uncertainty cost	3
4.	Case studies in machine performance modelling, Economics of machine selection	2
5.	Case studies in machine performance modelling	2
6.	Economics of Power and machine selection	2
	Total	**15**

Suggested Reading

- Hunt DR. 1986. Engineering Models for Agricultural Production. AVI Pub. Co., Westport, CT, USA.
- Hunt D and Wilson D. 2015. Farm Power and Machinery Management. Waveland Press, Illinois, USA.
- Singh S and Verma SR. 2009. Farm Machinery Maintenance and Management. DIPA, ICAR, New Delhi.

FMPE 613 MACHINERY FOR SPECIAL FARM OPERATIONS (2+0)

Aim

To bring to focus special farm operations that are not covered under conventional operations and the machinery used for such operations.

Theory

Unit I

Machinery for land development. Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers, laser levelers.

Unit II

Machines for plant protection, pneumatic, thermal type sprayers, aero/drone spraying and other methods of spraying, electrostatic charging, air sleeve boom sprayer, disinfection of seed beds by micro waves and other methods. Safety aids for operator and advances in plant protection method.

Unit III

Agricultural field machinery and its importance. Fertilizer and manure spreader.

Unit IV

Machines for residue management. Silage and hay making machines.

Unit V

Machinery for horticultural crops. Crop specific machines for cotton, sugarcane, forage/fodder. Machines for processing and handling of agricultural products.

Learning outcome

Understanding of the broad horizon of agricultural machinery used for specialized agricultural operations.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Machinery for land development	1
2.	Tractor operated and self-propelled machines for laying drainage system, sub surface drip laying machines, subsoiler, trenchers	2
3.	Laser levelers	2
4.	Machines for plant protection	1
5.	Pneumatic, thermal type sprayers	2
6.	Aero/drone spraying and other methods of spraying,	2
7.	Electrostatic charging, air sleeve boom sprayer	2
8.	Disinfection of seed beds by micro waves and other methods	1
9.	Safety aids for operator and advances in plant protection method	2
10.	Field plot machinery and its importance	1
11.	Fertilizer and manure spreader	2
12.	Machines for residue management (in situ)	4
13.	Machines for residue management (ex situ)	2
14.	Silage and hay making machines	3
15.	Machinery for horticultural crops	2
16.	Crop specific machines for cotton, sugarcane, forage/fodder	2
17.	Machines for processing and handling of agricultural products	1
	Total	**32**

Suggested Reading

- Bosoi ES, Sultan-Shakh EG, Smirnov II and Verniaev OV. 2016. *Theory, Construction and Calculation of Agricultural Machines*. Scientific Publishers.
- Kanafozski C and Karwowiki T. 1976. *Agricultural Machines: and Construction*. Vol. I&II, Translated and published by US Dept. of Agriculture and National Science Foundation, Washington, DC, USA.
- Kepner RA, Bainer R and Barger EL. 2017. *Principles of Farm Machinery*. CBS publishers and Distributors Pvt. Ltd, New Delhi, India.

FMPE 614 ERGONOMICS IN WORKING ENVIRONMENT (2+1)

Aim

To enable the student to understand the concept of designing the working environment and designing farm machinery and equipment to ensure operators comfort and safety.

Theory

Unit I

Musculoskeletal problems in sitting and standing postures-behavioral aspects of posture, body mechanics. Workspace design for standing and seated workers. Display units, controls and human-machine interaction, design of static work.

Unit II

Noise and noise control. Measurement of noise and safe limits. Protection from noise. Vibration and health. Vibrations generated by agricultural machines. Types of vibrations: Whole body vibrations and hand transmitted vibrations. Methods of measurements of vibrations, hazards of vibrations. Vibration White Fingers (VWF). Vibration reductions in agricultural machines.

Unit III

Working environment-heat and cold stress conditions. Thermal balance of human body. Measurement of thermal environment. Heat and cold stress condition. Thermoregulatory system of human body. Heat and cold acclimatization. Effect of climate on human performance. Environmental dust and its measurement: Organic and inorganic dust. Types of dust and their hazards: Respirable, thoracic and inhalable dust. Personal protection from dust.

Unit IV

Time motion study and its purpose. Application of Time motion study in agricultural and processing operations. Recent research works related to ergonomics in agriculture.

Practical

Design of workspace for static work in standing and sitting positions. Study of body mechanics and postures in design of agricultural machinery. Human energy expenditure, calibration of subjects, Human work load and its assessment. Study of work and rest schedule. Measurement of visibility of tractors. Measurement and control of noise in tractors and self-propelled machines. Measurement of human vibrations in farm tractors and agricultural machines. Study of dust generated in agricultural operations.

Learning outcome

Ability to design working environment of different agricultural machinery for efficient and safe operations.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Basics of body mechanics, stability and support	1
2.	Control of muscle function, fatigue and discomfort	1
3.	Musculoskeletal problems in sitting and standing posture	2
4.	Behavioural aspects of posture, risk factors for musculoskeletal disorders	1
5.	Importance of ergonomics in workspace design	1
6.	Workspace design for standing workers	1
7.	Workspace design for seated workers	1
8.	First hourly examination	1

9.	Visual display units, controls and human- machine interaction	1
10.	Design of static work	1
11.	Importance of noise control and safe limits for human	1
12.	Measurement of noise, reduction and protection	1
13.	Machine vibrations, human vibrations and health hazards	1
14.	Whole body vibrations and hand transmitted vibrations	1
15.	Methods of measurements of vibrations and health hazards	1
16.	Vibration reduction techniques for agricultural machines	1
17.	Mid-semester examination	1
18.	Working environment- heat and cold stress conditions, thermal balance of human body	1
19.	Measurement of thermal environment	1
20.	Thermo-regulatory system of human body, heat and cold acclimatization, effect of climate on human performance	2
21.	Environmental dust and its measurement, type of dust -organic and inorganic dust, dust health hazard	1
22.	Respirable, thoracic and inhalable dust, protection from dust	1
23.	Time motion study and its purpose	1
24.	Application of time motion study in agricultural and processing operations	1
25.	Recent research work related to physiological parameters of ergonomics in agriculture	1
26.	Recent research work related to tractor space layout and design of controls	1
27.	Recent research work related to noise studies on farm machines	1
28.	Recent research work related to vibrations studies on farm machines	1
29.	Recent research work related to accidents and safety studies on farm machines	1
30.	Revision and discussion	1
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Design of workspace for static work in standing or sitting posture	1
2.	Study of body mechanics and posture in design of agricultural machinery	2
3.	Study of displays and controls in tractors	1
4.	Calibration of subjects on ergometer and treadmill	2
5.	Human workload and its assessment	1
6.	Study of work and rest schedule	1
7.	Measurement of visibility to tractor operators	1
8.	Measurement of noise in tractors and self-propelled machines	1
9.	Measurement of machine component vibration	1
10.	Measurement of hand arm vibrations	1
11.	Measurement of whole-body vibrations	1
12.	Study of dust generated in agricultural operations	1
13.	Case study of design improvement in agricultural machine/ tool through ergonomic concept	1
14.	Practical examination	1
	Total	**16**

Suggested Reading

- Astrand PO, Rodahl K, Dahl HA and Stromme SB. 2003. *Textbook of Work Physiology: Physiological Bases of Exercise*. Champaign IL: Human Kinetics.

- Bridger RS. 2009. *Introduction to Ergonomics*. 3rd edition CRC Press, Boca Raton, USA.
- Gite LP, Majmudar J, Mehta CR and Khadatkar A. 2009. *Anthropometric and Strength Data of Indian Agricultural Workers for Farm Equipment Design*. Central Institute of Agricultural Engineering, Bhopal, India.
- Gite LP, Agrawal KN, Mehta CR, Potdar RR and Narwariya BS. 2019. *Handbook of*
- *Ergonomical Design of Agricultural Tools, Equipment and work Places*. Jain Brothers, New Delhi.
- Kroemer KHE and Grandjean E. 1997. *Fitting the Task to the Human: A Textbook of Occupational Ergonomics*. Taylor & Francis, Philadelphia, USA.
- Pearsons K. 2003, *Human Thermal environments: The Effects of Hot, Moderate and Cold Environment on Human Health, Comfort and Performance*. Taylor and Francis, New York, USA.
- Sanders MS and McCormick EJ. 1993. *Human Factors in Engineering and Design*. McGraw Hill, New York, USA.

9.2 Processing and Food Engineering

PFE 601 ADVANCES IN FOOD PROCESS ENGINEERING (2+1)

Aim

To acquaint and equip the students with the modern and latest techniques of food engineering.

Theory

Unit I

Preservation of foods: Physical and chemical methods, microbiological aspects, ndex bacteriology, process calculation and selection. Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, numerical computer simulation of heat transfer, aseptic processing.

Unit II

Low temperature preservation; Cooling and cold storage. Hurdle technology: Principles and applications. Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods. Microwave processing: Interaction with food materials, microwave equipment. Hydrostatic pressure treatment of food: Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications. Membrane concentration of liquid foods: Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.

Unit III

Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation. Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models. Pulsed electric field preservation: Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed

electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PFE technology, decontamination of microorganisms by surface treatment.

Unit IV

Extrusion cooking: Rheology of extrudates, ndex an models of single-screw extruder performance, non-newtonian models of single-screw extruder performance, single-screw extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, feed zone, behavior of more complex single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence- time distributions, recent developments, methods, equipment, design criteria of extruders.

Practical

Thermal processing of foods, sterilization, irradiation, membrane concentration, ultrasound, ohmic heating, pulsed electric field preservation, extrusion cooking, product quality determination. Visit of related food industries.

Learning outcome

Student's capability to process and preserve food products using advance techniques as per requirement of food industries.

Lecture schedule

S.No.	Topics	No. of Lectures
1.	Preservation of foods; Physical and chemical methods, microbiological aspects, ndex bacteriology, process calculation and selection.	3
2.	Thermal processing of canned foods: Introduction, commercial sterilization systems, thermal inactivation, kinetics of bacterial spores, heat transfer in canned foods, process calculations, Numerical computer simulation of heat transfer, aseptic processing.	4
3.	Low temperature preservation: Cooling, cold storage and CA storage.	3
4.	Hurdle technology; Principles and applications.	2
5.	Food irradiation: Advantages and applications, beneficial chemical and biological effects on foods, mechanisms of food irradiation, sources of food irradiation, criteria for judging the efficacy, dosimetry, radiation tolerance of foods, upper irradiation dose for foods, safety of irradiated foods.	2
6.	Microwave processing; Interaction with food materials, microwave equipment.	2
7.	Hydrostatic pressure treatment of food; Equipment, processing and effect on microorganisms. High pressure processing: Introduction, equipment and operation principles. Chemical and thermodynamic principles. Applications of HP to foods. Commercial high pressure equipment and applications.	2
8.	Membrane concentration of liquid foods; Principles, thermodynamics and osmotic pressure, mechanisms of membrane transport, membrane transport models.	2
9.	Application of heat energy and ultrasound; Effects of different environmental factors on microbial ultrasonic resistance, effects of treatment parameters on lethal effect of ultrasound, mechanism of action of inactivation of microorganisms and enzymes, cavitation	2
10.	Electrical resistance heating of food: Heat generation. Ohmic heating and moderate electric field: Introduction, microbial death kinetics, electrolytic effects, applications, ohmic heater, heating models.	2

11.	Pulsed electric field preservation; Principles and application, microbial inactivation mechanism, determinant factors in PFE technology, influence on food ingredients, pulsed electric field treatment unit, modeling PFE microbial inactivation, alternative applications of PEF technology, decontamination of microorganisms by surface treatment.	2
12.	Extrusion cooking; Rheology of extrudates, Newtonian and non-Newtonian models of single-screw extruder performance, extruder leakage flows, extruder die and its interaction with extruder behaviour, screw power demand, non-isothermal screw operation, single-screw designs, multiple-screw extruders, partially filled screws, analysis of complex screws, heat transfer in extruders, extruder residence- time distributions, recent developments, design criteria of extruders.	4
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Study of thermal processing of foods and equipment, viz. pasteurization and sterilization and tutorials.	2
2.	Study of different irradiation processes and equipments.	1
3.	Study of different membrane separation processes and equipments.	1
4.	Study of different ultrasound processes and equipments	1
5.	Study of different ohmic heating method and equipments.	1
6.	Study of different pulsed electric field preservation processes and equipments.	1
7.	Study of different extrusion cooking method and equipments.	2
8.	Product quality determination	2
9.	Visit of various food industries.	3
10.	Development of experimental setup by students	1
	Total	**15**

Suggested Reading

- Brennan JG, Butters JR, Cowell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier Publications.
- Fellows P. 1988. *Food Processing Technology: Principle and Practice*. VCH Publications.
- Geankoplis J Christie. 1999. *Transport Process and Unit Operations*. Allyn & Bacon.
- Henderson S and Perry SM. 1976. *Agricultural Process Engineering*. 5th Ed. AVI Publishing Company.
- McCabe WL and Smith JC. 1999. *Unit Operations of Chemical Engineering*. McGraw Hill.
- Sahay KM and Singh KK. 1994. *Unit Operation of Agricultural Processing*. VikasPublishing House Pvt Ltd.
- Singh RP and Heldman DR. 1993. *Introduction to Food Engineering*. Academic Press.
- Singh RP. 1991. *Fundamentals of Food Process Engineering*. AVI Publishing Company.

PFE 602 DRYING AND DEHYDRATION OF FOOD MATERIALS (2+1)

Aim

To acquaint and equip the students with the latest technologies of dehydration of food products and the design features of different dryers.

Theory

Unit I

Importance of drying, principles of drying, moisture determination, equilibrium moisture content, determination of EMC, methods and isotherm models. Psychrometry; Psychrometric terms, construction and use of psychrometric charts.

Unit II

Air flow and resistance, principles and equipment for air movement and heating, drying methods and theory of drying, dryers, classification and other allied equipment, thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.

Unit III

Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration, operation of dryers and their controls, selection of dryers, performance testing of grain dryers, drying characteristics of cereals, pulses and oilseeds, microwave drying, radio frequency drying and tunnel drying, principles and equipment.

Unit IV

Drying of liquid foods, spray drying, drum drying, freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying osmotic dehydration. Principles, methods, construction and adjustments, selection of dryers, heat utilization factor and thermal efficiency.

Practical

Experiments on batch type thin layer dryer, fluidized bed dryer, continuous flow mixing type dryer, continuous flow non mixing type dryer, sand medium dryer (conduction type drying), agricultural waste fired furnace dryer, spray dryer, drum dryer, foam mat drying and osmotic dehydration to evaluate the thermal efficiency and heat utilization factor.

Learning outcome

Student's capability to develop dehydrated food products with higher retention of nutrients using different drying techniques and equipment.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Importance of drying, principles of drying, moisture content determination, equilibrium moisture content, determination of EMC.	2
2.	Basic concepts associated with drying – Intermolecular forces, Water activity, Molecular mobility, Glass transition temperature, Isotherm models – Langmuir, BET Isotherm	3
3.	Psychrometry; Psychrometric terms, construction and use of psychrometric charts.	3
4.	Air flow and resistance, principles and equipment for air movement and heating	3
5.	Theory of drying, Dryers, Classification and other allied equipment,	2
6.	Thin layer drying of cereal grains, deep bed and continuous flow drying, drying models.	3
7.	Heat requirements and thermal efficiency of drying system, aeration, tempering and dehydration.	3
8.	Operation of dryers and their controls, selection of dryers, performance testing of grain dryers Drying characteristics of cereals, pulses and oilseeds,	3
9.	Microwave drying, radio frequency drying and tunnel drying, principles and equipment.	2

10.	Drying of liquid foods, spray drying, drum drying. Principles, methods, construction and adjustments.	2
11.	Freeze drying, foam mat drying, heat pump drying, refractance window drying, infrared drying, and osmotic dehydration. Principles, methods, construction and adjustments.	3
12.	Selection of dryers, heat utilization factor and thermal efficiency.	1
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Determination of moisture content with Oven method.	1
2.	Determination of moisture content (w.b.) with Universal/Digital moisture meter.	1
3.	Determination of moisture content (w b) with Infrared moisture meter.	1
4.	Determination of Equilibrium moisture content of grains.	1
5.	Drying of grains in a batch type thin layer dryer to evaluate the thermal efficiency and heat utilization factor.	1
6.	To evaluate the performance of fluidized bed dryer in terms of thermal efficiency and heat utilization factor.	1
7.	To draw a drying rate curve for wet grains in Satake test dryer i.e. Compartment type dryer.	1
8.	Drying of food materials in a solar assisted mechanical tray drying system.	1
9.	To dry grains in continuous flow mixing type dryer.	1
10.	To evaluate the performance of conduction type dryer.	1
11.	To determine the drying efficiency of agricultural waste fired furnace dryer.	1
12.	Drying of liquid food material in a spray dryer and evaluate its thermal efficiency and heat utilization factor.	1
13.	To evaluate the performance of a drum dryer.	1
14.	Experimentation on foam mat drying process.	1
15.	Experiment on osmotic dehydration of grapes.	1
	Total	**30**

Suggested readings

- Bala BK. 1998. *Drying and Storage of Cereal Grains*. Oxford and IBH.
- Brooker DB, Bakker Arkema FW and Hall CW. 1974. *Drying Cereal Grains*. The AVI Publishing Company.
- Chakraverty A and De DS. 1999. *Post-Harvest Technology of Cereals, Pulses and Oilseeds*. Oxford & IBH.
- Hall CW. 1970. *Drying Farm Crops*. Lyall Book Depot.
- Kudra and Mujumdar. 2009. *Advanced Drying Technologies*. CRC press.

PFE 603 TEXTURAL AND RHEOLOGICAL CHARACTERISTICS OF FOOD MATERIALS (2+1)

Aim

To acquaint and equip the students with advances in measurement of textural and rheological characteristics affecting the food quality.

Theory

Unit I

Rheological properties of foods; Food rheology, physical states of materials, classical ideal

material, rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior. Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.

Unit II

Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, ndex an fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry. Flow through a converging die, cogswell's equations, ndex 's equations, empirical method. Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.

Unit III

Objective and subjective measurements of texture; Texture classification, relation of food texture with structure and rheology, principles and practices of objective or instrumental texture measurements, fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation. Imitative and empirical measurements of texture; Tenderometer, brabenderfarinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.

Unit IV

Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids. Recent advances in textural, rheological and viscoelastic characteristics of foods and their associated mathematical models.

Practical

Determination of viscosity of liquid foods, gumminess, chewiness, springiness and hardness of various fruits, vegetables and processed foods using texture profile analysis. Determination of force-distance relationship. Sensory evaluation/ subjective measurement and correlation between subjective and objective measurements of foods.

Learning outcome

Student's capability to determine textural and rheological properties of food materials and their application in control of food processing operations.

Lecture schedule

S. No.	Topics	No. of Lectures
1.	Objective and subjective measurements of texture: Texture classification, relation of food texture with structure and rheology.	3
2.	Principles of Objective Texture Measurement.	2
3.	Practices of objective or instrumental texture measurements.	2
4.	Fundamental rheological tests, physiological aspects, mechanical aspects and viscosity measurements and relationship between fundamental tests and sensory evaluation.	2
5.	Imitative and empirical measurements of texture: Tenderometer, brabender farinograph, firmness meter, texture profile method, dynamic methods for evaluation of food texture, dimensional analysis of food texture, firmness and hardness measurement.	2

6.	Rheological properties of foods: Food rheology, physical states of materials, classical ideal material.	2
7.	Elastic–plastic behavior, visco-elastic behavior, creep behavior, dynamic visco-elastic behavior, flow behavior of fluids, creep, stress relaxation.	2
8.	Rheological models, elements in the models, electrical equivalence, maxwell model, Kelvin model and four element burger's model, stress-strain behavior.	2
9.	Viscometry; Capillary viscometry, casson model, flow rate equation, friction losses in pumping, turbulent flow, ndex an fluid, power law fluid, cone and plate viscometry, parallel plate viscometry, mixer viscometry.	2
10.	Flow through a converging die, cogswell's equations, ndex 's equations, and empirical method.	2
11.	Applications of stress and strain, shear modulus and shear loss modulus, storage compliance and loss compliance, comparison of moduli and compliances.	2
12.	Correlation between physical measurements and sensory assessments of texture and viscosity.	2
13.	Mathematical models and their application along with pipe line design and pump selection for non-newtonian fluids.	2
14.	Recent advances in textural, rheological and viscoelastic characteristicsof foods and their associated mathematical models.	2
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Introduction to Texture analyzer	1
2.	Study of different attachments of texture analyzer used in texture analysis of various agricultural commodities.	1
3.	To study the texture profile curve for food material	1
4.	To study the textural profile kinetics of various fruits	2
5.	To study the textural profile kinetics of various vegetables	2
6.	To study the textural profile kinetics of various processed foods	2
7.	To study the textural properties of liquid food	1
8.	To study the Compression, puncture, elongation and bending tests for food materials	3
9.	Introduction to Rapid Visco analyser	2
10.	Subjective measurement and correlation between subjective and objective measurements of foods.	1
	Total	**16**

Suggested Reading

- Bourne MC. 2002. *Food Texture and Viscosity: Concept and Measurement*. Academic Press.
- Deman JM. 1976. *Rheology and Texture in Food Quality*. AVI Publications.
- Mohsanin NN. 1989. *Physical Properties of Plant and Animal Material.* Vol. I, II. Gordon and Breach Science Publications.
- Steffe JF. 1992. *Rheology and Texture in Food Quality*. AVI Publications.

PFE 604 AGRICULTURAL WASTE AND BY-PRODUCTS UTILIZATION (2+1)

Aim

To acquaint and equip the students with the techniques of utilization of agricultural waste and by-products and also about development of value added products from wastes.

Theory

Unit I

Conversion processes: Thermo-chemical conversions, densification, combustion and gasification, extraction, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process. Agricultural wastes as paper, boards and fuel.

Unit II

Briquetting: Briquetted fuel from husk, hull and other wastes selection, design of briquetting machines. Utilization of shell, stem and stalk: Production of activated carbon. By-products of agro-industries: Rice mill, oil mill, cattle feed mill, valuable constituents and composition. Utilization of rice husk: Production of silica and cement from rice husk. Stabilization and storage of rice bran, extraction of rice bran oil.

Unit III

By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization. Rice germ and broken rice. Production of starch and infant food, industrial uses of starch. By-products of oil milling: Oil cake and defatted oil cake, cattle feed and industrial uses. Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries, thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.

Unit IV

By-products of sugar industry: Sugarcane tops, bagasse, molasses and pressmud, utilization as animal feed. By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.

Practical

Exercises on stepped grate and fixed grate rice husk furnaces, waste fired furnace, briquette machine, production of alcohol from waste materials, production and testing of paperboards and particleboards from agricultural wastes.

Learning outcome

Student's capability to develop processes for effective utilization of wastes generated through milling and processing of food materials.

Lecture schedule

S. No.	Topics	No. of Lectures
1.	Introduction to by-products and waste generation in agricultural production and processing system. Generation of agricultural and agro industrial by-products/ wastes, their properties, on site handling, storage and processing.	2
2.	Thermo-chemical conversions, biological conversions, anaerobic digestion, biochemical digestion process, digestion systems, energy from anaerobic digestion, cellulose degradation, fermentation process.	3

3.	Combustion and its types, theory, basic requirements for combustion, extraction.	2
4.	Gasification process, gasifiers- types and their functioning, factors affecting gasification process.	2
5.	Densification process, methods to densify materials, factors to be considered.	1
6.	Utilization of wastes for paper production, production of particle board.	1
7.	Briquetting process, methods, design of machinery used for briquette formation, basic requirements, factors affecting briquetting from husk, hull and other wastes selection.	2
8.	Utilization of rice husk: Production of silica and cement from rice husk, Stabilization and storage of rice bran, extraction of rice bran oil.	2
9.	Utilization of shell, stem and stalk: Production of activated carbon.	1
10.	By-products from rice milling operations, rice husk, rice bran, utilization in different materials.	3
11.	Waste from oil mill, cattle feed mill, their valuable constituents and composition, utilization.	2
12.	By-products of oil refining: Fatty acids/soap stock, wax and gum, characteristics and utilization.	1
13.	Rice germ and broken rice. Production of starch and infant food industrial uses of starch.	1
14.	By-products of oil milling: Oil cake and defatted oil cake, cattle feed and industrial uses.	1
15.	Utilization of starch and other industrial wastes: Microcrystalline cellulose, production of ethanol, wastes of tapioca starch industries.	2
16.	Thippi-utilization as fuel, extraction of starch by hydrolysis, utilization of starch for food, adhesives and feed purposes.	2
17.	By-products of sugar industry: Sugarcane tops, bagasse, molasses and press mud, utilization as animal feed.	2
18.	By-products of fruits and vegetables based agro-industries: Mango seed kernel and pineapple waste.	2
	Total	**32**

List of Practicals

S. No.	**Topics**	**No. of Lectures**
1.	To Determine of moisture content of biomass.	1
2.	To Determine of ash content of biomass.	1
3.	To determine Proximate analysis of biomass/waste/residue.	2
4.	Exercises on stepped grate and fixed grate rice husk furnaces.	2
5.	Exercises on waste fired furnaces.	1
6.	Exercises on combustion calculation.	1
7.	To study the briquetting machine.	1
8.	To study the various quality parameters of briquettes.	1
9.	To study the production of alcohol from waste materials.	1
10.	To study the production of paper boards and particle boards from agricultural wastes.	2
11.	To determine the properties of paper boards and particle boards from agricultural wastes.	2
	Total	**15**

Suggested Reading

- ASAE Standards. 1984. *Manure Production and Characteristics.*
- Bor SL. (Ed.). 1980. *Rice: Production and Utilization*. AVI Publ.
- Chahal DS. 1991. *Food, Feed and Fuel from Biomass.* Oxford & IBH.
- Chakraverty A. 1989. *Biotechnology and other Alternative Technologies for Utilisation of*
- *Biomass/Agricultural Wastes*. Oxford & IBH.
- Donald LK and Emert HG. 1981. *Fuels from Biomass and Wastes*. Ann. Arbor. Science Publ.
- Srivastava PK, Maheswari RC and Ohja TP. 1995. *Biomass Briquetting and Utilization*. Jain Bros.
- USDA. 1992. *Agricultural Waste Management Field Handbook*. USDA.

PFE 605 MATHEMATICAL MODELING IN FOOD PROCESSING (3+0)

Aim

To acquaint and equip the students with the mathematical modeling techniques and their applications in food processing

Theory

Unit I

An overview of the modeling process. Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems.

Unit II

Probability models, series and linear mathematical approximation, dynamic and interacting dynamic processes.

Unit III

Applications of mathematical modelling techniques to food processing operations like parboiling, convective drying, pasteurization, dehydration, shelf-life prediction, fermentation, aseptic processing, moisture diffusion, deep fat drying, microwave processing, infrared heating and ohmic heating.

Unit IV

Stochastic finite element analysis of thermal food processes. Neural networks approach to modelling food processing operations.

Learning outcome

Student's capability to develop models for food processing operations for prediction and control of operations.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	An overview of the modeling process.	2
2.	Introduction to mathematical, correlative and explanatory models. Formulation, idealization and simplification of the problems.	3
3.	Probability models, series and linear mathematical approximation	3
4.	Dynamic Mathematical Model, Analysis of Dynamic Mathematical Models, dynamic and interacting dynamic processes.	3
5.	Basic Concepts of Systems Analysis and Simulation.	2
6.	Common Heat and Mass Transfer Models Dimensional Analysis.	3
7.	Model-based techniques in food processing.	2

8.	Applications of mathematical modelling techniques to parboiling of rice, convective drying/ dehydration, deep fat drying etc.	4
9.	Applications of mathematical modelling techniques to pasteurization of milk and juices.	4
10.	Applications of mathematical modelling techniques to fermentation, aseptic processing, moisture diffusion.	4
11.	Applications of mathematical modelling techniques in shelf-life prediction of agricultural commodities.	3
12.	Applications of mathematical modelling techniques to microwave heating, infrared heating and ohmic heating.	3
13.	Stochastic finite element analysis of thermal food processes.	3
14.	Probability models, series and linear mathematical approximation	3
15.	Neural networks approach to modelling food processing operations.	3
	Total	**45**

Suggested Reading

- Fischer M, Scholten HJ and Unwin D. 1996. *Spatial Analytical Perspectives on GIS*. Taylor & Francis.
- Fish NM and Fox RI. 1989. *Computer Application in Fermentation Technology: Modelling and Control of Biotechnological Processes*. Elsevier.
- Gold HJ. 1977. *Mathematical Modelling of Biological Systems – An Introductory Guidebook*. John Wiley & Sons.
- Hunt DR. 1986. *Engineering Models for Agricultural Production*. The AVI Publ.
- Koeing HE, Tokad Y, Kesacan HK and Hedgers HG. 1967. *Analysis of Discrete Physical Systems*. McGraw Hill.
- Meyer JW. 2004. *Concepts of Mathematical Modeling*. McGraw Hill.
- Peart RM and Curry RB. 1998. *Agricultural Systems, Modelling and Simulation*. Marcel Dekker.
- Tijms HC. 1984. *Modelling and Analysis. A Congrtational Approach*. Wiley Publ.

PFE 606 BIOPROCESS ENGINEERING (2+1)

Aim

To acquaint and equip the students with the basic principles of biochemical process engineering.

Theory

Unit I

Applications of engineering principles: Mass and energy balance, fluid flow principles, Unit operations of process engineering.

Unit II

Fundamentals of growth kinetics, maintenance energy and yield concepts, principles of media sterilization, media formulations of industrial fermentation.

Unit III

Aerobic and agitated rheology of fermentative fluids, design and scale-up of bioreactors, enzyme reactors.

Unit IV

Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.

Practical

Kinetics of one substitute reactions, kinetics of growth in batch cultures, design consideration for bioreactors, media preparation and sterilization, microprocessor based monitoring of bioprocess parameters.

Learning outcome

Student's capability to calculate the mass and energy balances in ant process operations, understanding growth kinetics and design bioreactors as per requirement of food industries.

Lectures Schedule

S. No.	Topics	No. of Lectures
1.	Basic engineering principles and their applications. Use of units and dimensions.	3
2.	Mass balance: steady and unsteady. Problem solving involving blending, separation, drying, growth, recycling etc.	3
3.	Energy balance in food processing operations. Use of steam tables in calculation of heat requirements etc.	3
4.	Fluid flow principles: Static and dynamic. Concept of viscosity. Types of flow. Flow through pipes. Mass and energy balance in fluid flow. Calculation of pressure drop in pipes.	4
5.	Fundamentals of growth kinetics, maintenance energy and yield concepts.	3
6.	Principles of media sterilization, media formulations of industrial fermentation.	3
7.	Aerobic and agitated rheology of fermentative fluids.	3
8.	Design and scale-up of bioreactors, enzyme reactors.	3
9.	Principles of recovery of fermented products in bio-processing, instrumentation, transport phenomenon.	3
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	To study the instruments used for measurement of temperature, relative humidity, flow rate, pressure, wind velocity, solar radiation etc.	1
2.	Use of units, dimensions and basic mathematical applications.	1
3.	To judge the students ability for solving mass balance problems.	2
4.	To judge the students ability for solving Energy balance problems.	2
5.	To study the kinetics of one substitute reactions.	1
6.	To assess the kinetics of growth in batch cultures.	1
7.	To study the order of reactions involving single/multiple reactants/products.	1
8.	To study the various thermal and structural parameters affecting the design of bioreactors.	1
9.	To assess the student's ability for design of bioreactors by solving related numerical problems.	2
10.	To prepare various media cultures and assess their effectiveness with time	1
11.	To study the mechanism of sterilization of cultures.	1
12.	To study the various electronic gadgets for continuous monitoring of bioprocess parameters	1
	Total	**15**

Suggested Reading

- Brennan JG, Butters JR, Cavell ND and Lilly AEI. 1990. *Food Engineering Operations*. Elsevier.
- Coulson JM and Richadson JF. 1999. *Chemical Engineering*. Vols. II, IV. The Pergamon Press.
- Greanoplis JC. 1999. *Transport Process and Unit Operation*. Allyn & Bacon
- Treybal RE. 1981. *Mass Transfer Operations*. 3rd Ed. Harper & Row.

9.3 Soil and Water Conservation Engineering

SWCE 601 ADVANCES IN HYDROLOGY (2+1)

Aim

To provide comprehensive knowledge to the students about hydrologic models, flood frequency analysis and formulation of statistical models.

Theory

Unit I

Hydrologic models, processes and systems. Uncertainty in hydrological events. Statistical homogeneity.

Unit II

Probabilistic concept. Frequency analysis. Probability distribution of hydrological variables. Confidence intervals and hypothesis testing.

Unit III

Simple and multiple linear regressions, correlation, statistical optimization and reliability of linear regression models. Analysis of hydrologic time series and modeling. Auto–correlation, correlogram and cross-correlation analysis.

Unit IV

Markov processes, stochastic hydrologic models including Markov chain models. Generation of random variates. Hydrology of extremes. Area-Duration-Frequency curves. Regional flood frequency analysis.

Unit V

Formulation of various steps involved in formulation of statistical models and their application in hydrology.

Practical

Parametric and non-parametric test of time series data. Development of probabilistic and deterministic models for time series data of rainfall and runoff. Development of hydrologic models and frequency analysis for specified data set using SPSS and other software used in hydrologic modeling.

Learning outcome

The students will be able to develop the hydrologic modeling and find out their trend as well as periodic component. To develop the stochastic and deterministic models for forecasting precipitation for prediction of floods and droughts.

Lecture Schedule

S. No.	Topics	No. of Lectures

1.	Hydrologic models, processes and systems	1
2.	Uncertainty in hydrologic events risks, uncertainty	1
3.	Statistical homogeneity in hydrologic processes	1
4.	Probability, total probability theorem, Bayes theorem	2
5.	Moment generating function, statistical parameters	1
6.	Probability distribution of hydrologic variables	2
7.	Confidence interval one sided, two-sided, Hypothesis testing test statistics	2
8.	Regression analysis, simple regression, confidence interval on regression coefficient, regression line, inference on regression	3
9.	Multiple linear regression	2
10.	Optimization of regression coefficients, Statistical optimization and reliability of linear regression models	3
11.	Time series analysis, components, stationarity, Auto correlation, correlograms, Cross correlation analysis	3
12.	Generating processes, Markov process- first order, higher order	2
13.	Statistical principles and techniques for time series modeling	2
14.	Markov chain models, Examples of Markov chain models in hydrology	2
15.	Autoregressive models, Autoregressive modeling of annual time series, Examples of autoregressive modeling	3
16.	Hydrology of climate extremes. Area-duration-frequency curves. Regional flood frequency analysis	2
17.	Formulation of various steps involved in formulation of statistical models and their application in hydrology	2
	Total	**34**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Study of parametric and non-parametric test of time series data	4
2.	Development of probabilistic models for time series data of rainfall and runoff	2
3.	Development of deterministic models for time series data of rainfall and runoff	2
4.	Development of hydrologic models for specified data set using SPSS and other software used in hydrologic modeling	2
5.	Development of frequency analysis for specified data set using SPSS and other software used in hydrologic modeling	2
6.	Development of the stochastic models for forecasting precipitation for prediction of floods and droughts	2
7.	Development of deterministic models for forecasting precipitation for prediction of floods and droughts	2
	Total	**16**

Suggested reading

- Garg SK. 1987. *Hydrology and Water Resources Engineering*. Khanna Publications.
- Hann CT. *Advanced Hydrology*. Oxford Publications House.
- Linseley RK Jr, Kohler MA and Paulhus JLH. 1975. *Applied Hydrology*. McGraw Hill.
- Mutreja KN. 1986. *Applied Hydrology*. Tata McGraw Hill.
- Singh VP. 2010. *Hydrological Modelling*. Springer, New York.

SWCE 602 SOIL AND WATER SYSTEMS SIMULATION AND MODELING (2+1)

Aim

To acquaint students about the rainfall-runoff models, sediment model, overland and channel flow simulation and decision support systems using simulation models.

Theory

Unit I

Models and their classification, simulation procedure. Rainfall-runoff models. Infiltration models, evapo-transpiration models, structure of a water balance model.

Unit II

Overland and channel flow simulation. Modeling approaches and parameters. Stream flow statistics. Surface water storage requirements.

Unit III

Flood control storage capacity and total reservoir capacity. Surface water allocations. Palaeo-channels. Ground water models.

Unit IV

Design of nodal network. General systems frame work. Description of the model. Irregular boundaries. Decision support system using simulation models. Monte- Carlo approach to water management.

Unit V

Stanford watershed model and input data requirements of various hydrologic modeling systems. Soil water assessment tool (SWAT). Groundwater modeling and solute transport.

Practical

Rainfall-runoff models. Infiltration models. Stanford watershed model (SWM). Channel flow simulation problems. Stream flow statistics. Model parameters and input data requirements of various software's of surface hydrology and groundwater. Hydrologic modeling system. Soil water management model. Soil water assessment tool (SWAT). Catchments simulation hydrology model. Stream flow model and use of dimensionless unit hydrograph. Generalized groundwater models.

Learning outcome

The students will be able to develop the model for overland and channel flow simulation, which can be used for watershed management and planning and also able to simulate the ground water and surface water by developing the ground water model and runoff models.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Models and their classification, simulation procedure	2
2.	Rainfall-runoff models	3
3.	Infiltration models, evapo-transpiration models, structure of a water balance model	2
4.	Overland and channel flow simulation	2
5.	Modeling approaches and parameters. Stream flow statistics	2
6.	Surface water storage requirements	1
7.	Flood control storage capacity and total reservoir capacity	2
8.	Surface water allocations	1
9.	Palaeo-channels	1

10.	Ground water models	2
11.	Design of nodal network	1
12.	General systems frame work	1
13.	Description of the model	1
14.	Irregular boundaries	1
15.	Decision support system using simulation models	2
16.	Monte-Carlo approach to water management	2
17.	Stanford watershed model and input data requirements of various hydrologic modeling systems	2
18.	Soil water assessment tool (SWAT)	2
19.	Groundwater modeling and solute transport and channel flow simulation	2
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Rainfall-runoff models	2
2.	Infiltration models	1
3.	Stanford watershed model (SWM)	1
4.	Channel flow simulation problems	1
5.	Stream flow statistics	2
6.	Model parameters and input data requirements of various software's of surface hydrology and groundwater	2
7.	Hydrologic modeling system. Soil water management model	2
8.	Soil water assessment tool (SWAT). Catchments simulation hydrology model	2
9.	Stream flow model and use of dimensionless unit hydrograph	1
10.	Generalized groundwater models	2
	Total	**16**

Suggested Reading

- Biswas AK. 1976. *Systems Approach to Water Management*. McGraw Hill.
- Cox DR and Mille HD. 1965. *The Theory of Stochastic Processes*. John Wiley & Sons.
- Eagleson PS. 1970. *Dynamic Hydrology*. Mc Graw Hill.
- Himmel Blau DM and Bischoff KB. 1968. *Process Analysis and Simulation Deterministic Systems.* John Wiley & Sons.
- Linsley RK, Kohler MA and Paulhus JLH. 1949. *Applied Hydrology*. McGraw Hill.
- Schwar RS and Friedland B. 1965. *Linear Systems.* McGraw Hill.
- Ven Te Chow, David R Maidment and Mays LW. 1998. *Applied Hydrology*. McGraw Hill.

SWCE 603 RESERVOIR OPERATION AND RIVER BASIN MODELING (2+1)

Aim

To provide comprehensive knowledge to the students about water management plans, demand analysis and water resources planning in river basins including stochastic and deterministic modeling.

Theory

Unit I

Water resources system analysis: Techniques, concept, objectives and applications.

Unit II

Identification and evaluation of water management plans. Demand analysis, policy formulation. Water resources planning objectives. Water resources planning under uncertainty.

Unit III

Definition of terminologies and basic concepts. Theories and principles of IRBM processes/phases in integrated river basin management. River basins, river functions. Human interventions and impacts. River basins in India, related case studies. Water resources planning in river basins. Operational management, tools and methods. Monitoring, acquisition and processing of water resource data.

Unit IV

Statistical methods. Decision support systems. Deterministic river basin modeling. Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis, single and multi-reservoir operation models. Economics and finance.

Unit V

Stochastic river basin modeling: Single reservoir design and operation, multisite river basin models, stochastic linear programming operation models.

Practical

Development of regression models, stochastic models and deterministic models for river basin based on stream flow data. Estimation of reservoir storage and preparation of operation models.

Learning outcome

The students will be able to develop the model for effective water resources planning for river basins, identification and evaluation of water management plans as well as in-depth knowledge of stochastic and deterministic modeling.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Introduction–Concepts of Systems and Systems Analysis; Techniques, objectives and applications Applications of Water resources system analysis	2
2.	Identification and evaluation of water management plans-water demand analysis, Water resources planning objectives	1
3.	Water resource planning and management approaches-Top-Down Planning and Management; Bottom-Up Planning and Management	2
4.	Integrated Water Resources Management	1
5.	Water resource management policy formulation, Water resources planning under uncertainty	1
6.	River basins, river functions, Theories and principles of IRBM processes/phases in integrated river basin management	1
7.	Human interventions and impacts in in integrated river basin management	1
8.	River basins in India- related case studies	1
9.	Water resources planning in river basins- Operational management, tools and methods	2
10.	Water resources planning in river basins – Monitoring, acquisition and processing of water resource data	2
11.	Economic Considerations in Water Resources Planning	1

12.	Deterministic river basin modeling-Stream flow estimation, estimating reservoir storage, mass diagram analysis, sequent peak analysis	6
13.	Deterministic river basin modeling- Reservoir Sizing; Reservoir Operation – standard operating policy, optimal operating policy; multi-reservoir systems,	1
14.	Concept of Reliability	2
15.	Stochastic river basin modeling: Basic probability theory,	3
16.	Single reservoir design and operation-Chance constrained Linear Programming for reservoir operation and design	1
17.	Stochastic river basin modeling: multisite river basin models, Model Formulations and Case Studies- Conjunctive use of ground and surface water; Crop yield optimization, Multi-basin and multi-reservoir systems basins, river functions, Theories and principles of IRBM processes/phases in integrated river basin management	3
	Total	**33**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Development of regression models	1
2.	Regression analysis	1
3.	Correlation analysis	1
4.	Simple Linear Regression and coefficient of determination	1
5.	Discrete and Continuous probability – Random Variable and Variate	1
6.	Deterministic models for river basin based on stream flow data	1
7.	Stochastic models for river basin based on stream flow data	1
8.	Stochastic river basin modeling	1
9.	Stochastic linear programming operation models	1
10.	Single and multi-reservoir operation models	1
11.	Evaluation of water management plans	1
12.	Evaluation of demand analysis	1
13.	Stream flow estimation	1
14.	Estimation of reservoir storage	1
15.	Preparation of operation models	1
16.	Deterministic river basin planning model	1
	Total	**16**

Suggested Reading

- Chaturvedi MC 1984. System Approach to Water Resources Planning and Management.
- Loucks DP et al. 1980. Water Resources System Planning and Analysis. Prentice Hall, NJ.
- Major DC and Lenton RL. 1979. Applied Water Resources System Planning. Prentice Hall Inc., New Jersey.

SWCE 604 MODELING SOIL EROSION PROCESSES AND SEDIMENTATION (2+1)

Aim

To acquaint students about the concept of modeling upland erosion, reservoir sedimentation and sediment yield models for estimation of soil erosion.

Theory

Unit I

Mechanics of soil erosion. Erosion-sedimentation systems of small watersheds. Overland flow theory and simulation. Basic theory of particle and sediment transport. Sediment deposition processes.

Unit II

Modeling upland erosion and component processes. Modes of transport and transport capacity concept and computation. Channel erosion. Erosion and sediment yield measurement and estimates.

Unit III

Reservoir sedimentation surveys and computation. Classification of models, structure and mathematical bases of sediment yield models. Nature and properties of sediment: Individual and group of particles. Critical tractive force, lift and drag forces. Shield's analysis.

Unit IV

Calibration and testing of models. Universal soil loss equation, its modification and revisions. Stochastic and dynamic sediment yield models.

Unit V

Evaluation of erosion control measures. Computer models used for hydrologic and/ or watershed modeling.

Practical

Computation of soil erosion ndex. Estimation of soil erodibility factor. Design of erosion control structures. Computation of suspended load and sediment load using empirical formulae. Application of sediment yield models. Prediction of sediment loss. Computation of reservoir sedimentation, sounding method.

Learning outcome

The students will be able to estimate the sediment from the particular watershed by using various instruments. Development of the common understanding of mechanics of sediment transportation process and remedies to reduce sedimentation of watersheds

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Mechanics of soil erosion	1
2.	Erosion-sedimentation systems of small watersheds	1
3.	Overland flow theory and simulation	2
4.	Basic theory of particle and sediment transport. Sediment deposition processes	2
5.	Modeling upland erosion and component processes	2
6.	Modes of transport and transport capacity concept and computation	2
7.	Channel erosion	1
8.	Erosion and sediment yield measurement and estimates	1
9.	Reservoir sedimentation surveys and computation	2
10.	Classification of models, structure and mathematical bases of sediment yield models	2
11.	Nature and properties of sediment: Individual and group of particles	2
12.	Critical tractive force, lift and drag forces	2
13.	Shield's analysis	2
14.	Calibration and testing of models	2
15.	Universal soil loss equation, its modification and revisions	2
16.	Stochastic and dynamic sediment yield models	2
17.	Evaluation of erosion control measures	2
18.	Computer models used for hydrologic and/or watershed modeling	2
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Computation of soil erosion index	2
2.	Estimation of soil erodibility factor	2
3.	Design of erosion control structures	4
4.	Computation of suspended load and sediment load using empirical formulae	2
5.	Application of sediment yield models	2
6.	Prediction of sediment loss	2
7.	Computation of reservoir sedimentation, sounding method	2
	Total	**16**

Suggested Reading

- Garde RJ and Ranga Raju KG. 1977. Mechanics of Sediment Transport and Alluvial Stream Problems.Wiley Eastern Ltd.
- Morgan RPC (Ed. D A Davison). 1986. Soil Erosion and Conservation. ELBS.
- Longman USDA. 1969. A Manual on Conservation of Soil and Water. Oxford & IBH.
- Tripathi RP and Singh HP. 1993. Soil Erosion and Conservation. Publisher- New Age International, New Delhi.

SWCE 605 WASTE WATER TREATMENT AND UTILIZATION (2+)

Aim

To acquaint students about types of waste water and the various treatment measures along with the utilization of waste water in agriculture and other sectors.

Theory

Unit I

Types of waste water, causes of pollution, analysis of pollutants in the waste effluents, Biological wastewater treatment, biological sludge treatment. Biological systems: Fundamentals of microbiology and biochemistry, bioenergetics and metabolism, kinetics of biological growth. Process analysis: Reaction rates, effect of temperature on reaction rate, enzyme reaction and kinetics, effect of temperature on reaction rate. Reactor analysis, residence time distribution.

Unit II

Sewerage system: Domestic wastewater characteristics, flow equalization, population equivalent, treatment flow chart. Primary, secondary and tertiary treatment of domestic wastewater. Downstream wastewater treatment for reuse and recycle. Need for downstream processing. Guidelines for wastewater recycling. Small and package plants for wastewater treatment.

Unit III

Activated sludge process: Substrate utilization and biomass growth, Monod's kinetics, estimation of kinetic parameters. Process Description and its Modification, Process design, process performance evaluation, trouble shooting. Nitrogen removal- Biological nitrification and denitrification.

Unit IV

Activated sludge process design for nutrient removal. Process operation: (F/M), mean cell residence time, oxygen requirement. Biological and chemical phosphorus removal, Sedimentation of activated sludge. Advanced activated sludge process- Sequencing Batch reactor, Oxidation ditch and membrane bioreactors.

Unit V

Biofilm process: Trickling filter, biotower, rotational biological contactor, integrated activated

sludge and biofilm processes. Stabilization ponds and aerated lagoons: Types and their description, design, operation and maintenance. Anaerobic processes: Process description, process design, operation and maintenance, sludge digestion. Sludge treatment-thickening, dewatering-mechanical and sludge drying beds. Utilization of waste water in agriculture and other sectors.

Learning outcome

Students will be able to have in-depth knowledge about waste water treatment methods, sewerage system, activated sludge process, biofilm process. The student will also eXpose to use of waste water in agriculture and other sectors.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Status of wastewater in India, Sources of contamination and characterization of urban and rural wastewater for irrigation	2
2.	Water quality: Physical, chemical and biological parameters of wastewater	2
3.	Wastewater quality requirement: Potable water standards, wastewater effluent standards, water quality indices. Irrigation water quality standards both national and global and guidelines for their restricted and unrestricted uses.	2
4.	Different types of wastewater, pollutants and contaminants.	1
5.	Impact of wastewater on ecosystem, eutrophication, biomagnification, water borne diseases.	2
6.	Key drivers of wastewater use in agriculture and existing approaches for regulating wastewater reuse in agriculture	2
7.	Selection of appropriate forestry trees, fruits, vegetables, oilseeds and food grain crop for wastewater utilization and practices used for irrigation	3
8.	Health Risks Associated with the Use of Wastewater for Irrigation	1
9.	Wastewater treatment methods: Physical, chemical and biological.	3
10.	Choice of (Cost-Effective) Wastewater Treatment Systems for Irrigation	2
11.	General water treatments: Wastewater recycling, constructed wetlands, reed bed system.	2
12.	Carbon foot prints of wastewater reuse. Environmental standards.	2
13.	Management of health and environmental risks of wastewater irrigation	1
14.	Regulation and environmental impact assessment (EIA): Environmental standards-CPCB Norms for discharging industrial effluents to public sewers. Valuation of environmental impacts.	3
15.	Impact on groundwater resources and soil health, EIA process, Impact on groundwater resources and soil health, EIA process, Stages of EIA-monitoring and auditing. Environmental clearance procedure in India	3
16.	Economics of wastewater irrigation	1
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Study on physical, chemical and biological parameters of wastewater	1
2.	Determination of EC and pH of wastewater	1
3.	Determination of BOD of wastewater	1
4.	Determination of COD of wastewater	1
5.	Determination of TSS and TDS of wastewater	1

6.	Determination RSC of wastewater	1
7.	Determination of e-coli in the wastewater	1
8.	On field demonstration of wastewater use for the irrigation	1
9.	Determination of nutrient (N, P and K) concentration in wastewater	2
10.	Field demonstration of impact of waste water on eco-system and human health.	1
11.	Study on various wastewater treatment methods	2
12.	Study on effect of wastewater on contamination of ground water	1
13.	Visit of village pond treatment nearby area	1
14.	Visit of sewerage treatment plant nearby area	1
	Total	**16**

Suggested Readings

- Droste RL. 1997. Theory and Practice of Water and Wastewater Treatment. John Wiley.
- Metcalf and Eddy. 2003. Wastewater Engineering. 4th Ed., McGraw Hill.
- Qasim SR. 1999. Wastewater Treatment Plants – Planning, Design and Operation. CRC Press, Florida.
- Ramalho RS. Wastewater Treatment. Wiley.

SWCE 606 HYDRO-CHEMICAL MODELING (2+0)

Aim

To provide comprehensive knowledge to the students about hydrodynamics of flow through porous media and development of analytical, statistical and numerical models.

Theory

Unit I

Review of hydrodynamics in flow through porous media. Miscible displacement, physical processes.

Unit II

Breakthrough curves and mathematical models for miscible displacement. Hydrodynamic dispersion convection equations and its solutions.

Unit III

Statistical models for dispersion. Gaseous (CO_2 and O_2) diffusion equation.

Unit IV

Heat flow through soil by conduction. Concept of adsorption in solute transport.

Unit V

Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.

Learning outcome

Students will be able to demonstrate understanding of hydrodynamics of fluid transport through modeling and will be able to do water quality analysis of lakes and reservoir based physical and chemical characteristics. Develop water reclamation and water reuse plans for irrigation and industries.

Lecture Schedule

S. No.	Topics	No. of

		Lectures
1.	Review of hydrodynamics in flow through porous media	7
2.	Miscible displacement, physical processes, breakthrough curves	2
3.	Mathematical models for miscible displacement	5
4.	Hydrodynamic dispersion convection equation and its solutions	4
5.	Heat flow through soil by conduction	2
6.	Concept of adsorption in solute transport	2
7.	Analytical and numerical models of contaminant transport in unsaturated soil profile and groundwater aquifers.	6
8.	Statistical models for dispersion	3
9.	Gaseous (CO_2 and O_2) diffusion equation. Of hydrodynamics in flow through porous media	3
	Total	**34**

Suggested Reading

- Larry W Mays 1996. Water Resources Handbook. Mc Graw Hill.
- Metcalf and Eddey 1994. Wastewater Treatment Engineering and Reuse. John Wiley.
- Soli J Arceivala 1998. Wastewater Treatment for Pollution Control. Tata Mc Graw-Hill

10. Minor Courses

REE 602 THERMO-CHEMICAL CONVERSION OF BIOMASS (2+1)

Aim

To help students to understand in depth knowledge of thermo-chemical conversion of organic waste, combustion chemistry and different heat-based conversion technologies for fuel and power generation.

Theory

Unit I

Biomass: Characterization, resources and energy recovery. Thermo-chemical conversion of organic wastes. Chemical thermodynamics, stoichiometry and thermodynamics.

Unit -II

Combustion of fuels: Solid fuels, stoker, types, fluidised bed. Liquid fuels: Atomization, vapour concentration, combustion phenomena. Gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.

Unit III

Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification. Coal gasification technologies. Syngas characteristics. Tar and particulates in gasification. Integrated coal gasification. Gas turbine technologies.

Unit IV

Pyrolysis: Models, regimes, kinetics and effect of process parameters. Radiant heat flux, heterogeneous reactions, wall heat transfer. Fluidised bed reactors: Heat transfer circulating beds, moving bed reactor.

Unit V

To refaction and charcoal production: Carbonization parameters, temperature zone, input output, energy density ratios and characterization of finished products.

Practical

Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels.TGA studies. Liquid and gaseous burners, flame studies, flue gas, heat budgeting. Kinetic study on gasifiers. Producer gas-based power generation systems. Kinetic and model studies for torrefaction, char coal and bio oil production.

Learning outcome

Students will enable to critical analysis of combustion of fuel and system design for thermos chemical conversion technologies for domestic and industrial applications.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Biomass: Characterization, resources and energy recovery.	2
2.	Thermo-chemical conversion of organic wastes.	1
3.	Chemical thermodynamics and stoichiometry.	3
4.	Combustion of solid fuels: stoker, types, fluidized bed.	2
5.	Combustion of liquid fuels: Atomization, vapour concentration, combustion phenomena.	2
6.	Combustion of gaseous fuel: Flame characteristics, inflammability limits, submerged combustion, combustion with explosion flame, pulsating combustion.	2
7.	Biomass Gasification: Gasifier configurations, classification, entrained flow, fluidized bed, moving bed, plasma gasification.	3
8.	Coal gasification technologies, Integrated coal gasification.	2
9.	Syngas characteristics, Tar and particulates in gasification.	2
10.	Gas turbine technologies.	2
11.	Pyrolysis: Models, regimes, kinetics and effect of process parameters.	2
12.	Radiant heat flux, heterogeneous reactions, wall heat transfer.	2
13.	Fluidized bed reactors: Heat transfer circulating beds, moving bed reactor.	2
14.	Torrefaction and charcoal production: Carbonization parameters, temperature zone, input output	2
15.	Energy density ratios and characterization of finished products.	2
	Total	**31**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Combustion thermodynamics and phenomenon in solid, liquid and gaseous fuels	2
2.	Determination of efficiency of improved chulha through water boiling test procedure.	1
3.	Thermo-gravimetric analysis of biomass sample	1
4	Study of liquid burners	1
5.	Study of gaseous burners	1
6.	Flame studies and flue gases	1
7.	Study on heat budgeting	1
8.	Study on kinetics of fluidized bed gasifier	1
9.	Producer gas-based power generation systems	1
10.	Kinetic and model studies for Torrefaction	2
11.	Kinetic and model studies for charcoal production.	2

12.	Kinetic and model studies for bio-oil production.	2
	Total	**16**

Suggested Reading

- Culp AW. 1979. Principles of Energy Conversion. McGraw Hill Book Company, New York, USA.
- Glassman I. 1987. Combustion. Academic Press Inc. Orlando, Florida, USA.
- Klan E. 1985. Energy from Biomass and Wastes. Institute of Gas Technology, Chicago.
- Kiang YH. 1981. Waste Energy Utilization Technology. Marcel Dekkar, New York, USA.
- Rezaiyan J and Cheeremisinoff NP. 2005. Gasification Technologies–A Primer for Engineers and Scientists. CRC Press, Taylor and Francis group, New York, USA.
- Tchobanoglous G and Elliassen HTR. 1978. Solid Wastes. McGraw Hill Book Company, New York, USA.
- Wilson DG and Reinhold VN. 1977. Hand Book of Solid Waste Management. Van Nostrand Reinhold Company, New York.
- Sivanandam SN and Deepa SN. 2011. Principles of Soft Computing. Wiley India Pvt. Ltd., 2nd Edition.
- Sivanandam SN and Deepa SN. 2013. Principles of Soft Computing. Wiley India.

REE 609 ENERGY PLANNING, MANAGEMENT AND ECONOMICS (3+0)

Aim

To acquaint and equip with energy planning, management and economical evaluation for agricultural production system.

Theory

Unit I

Energy resources on the farm: Conventional and non-conventional forms of energy and their use. Heat equivalents and energy coefficients for different agricultural inputs and products.Pattern of energy consumption and their constraints in production of agriculture.Direct and indirect energy.

Unit II

Energy audit of production agriculture and rural living and scope of conservation. Identification of energy efficient machinery systems, energy losses and their management.

Unit III

Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources. Energy conservation planning and practices.

Unit IV

Energy forecasting, energy economics, energy pricing and incentives for energy conservation, factors effecting energy economics. Techno-economic evaluation of RET's, computation of programme for efficient energy management.

Learning outcome

The student will be able to quantify, analyze and forecast the demand and supply of different energy for agriculture production system.

Lecture Schedule

S. No.	Topics	No. of Lectures

1.	Energy resources on the farm: Conventional and non-conventional forms of energy and their use.	3
2.	Heat equivalents and energy coefficients for different agricultural inputs and products.	3
3.	Pattern of energy consumption and their constraints in production agriculture. Direct and indirect energy.	3
4.	Energy audit of production agriculture and rural living and scope conservation.	4
5.	Identification of energy efficient machinery systems	3
6.	Energy losses and their management.	4
7.	Energy analysis techniques and methods: Energy balance, output and input ratio, resource utilization, conservation of energy sources.	4
8.	Energy conservation planning and practices.	4
9.	Energy forecasting	3
10.	Energy pricing and incentives for energy conservation,	3
11.	Energy economics and factors affecting energy economics	4
12.	Techno-economic evaluation of RET's	4
13.	Computation of programme for efficient energy management.	3
	Total	**45**

Suggested Reading

- Fluck RC and Baird CD. 1984. Agricultural Energetics. AVI Publication, United State.
- Kennedy WJ and Turner WC. 1984. Energy Management. Prentice Hall, New Jersey.
- Pimental D. 1980. Handbook of Energy Utilization in Agriculture. CRC Press, Florida.

REE 610 RENEWABLE ENERGY FOR INDUSTRIAL APPLICATION (2+1)

Aim

To provide the knowledge regarding the energy consumption pattern in agro based industries, quantification techniques and identification of opportunities for renewable energy sources.

Theory

Unit I

Elucidation of unit operations in industry.Energy quantification techniques, system boundary, estimation of productivity, plant capacity utilization, energy density ratio and energy consumption pattern.Energy flow diagram conservation opportunities identification.

Unit II

Solar energy for industrial application: Solar water heating, steam solar cooking system, industrial solar dryer and solar process heat, solar cooling system (refrigeration, air conditioning and solar architecture technology), solar furnace and solar green house technology for high-tech cultivation. Solar photovoltaic technology for industrial power.

Unit III

Bio energy for industrial application: Quantification of industrial bio-waste, characterization, power generation through bio-methanation, gasification and dendro thermal power plant.

Unit IV

Wind energy: Aero generator of new era and national and international state of art in wind power generation. Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.

Practical

Elucidation and energy consumption for unit operations in industry. Study of energy quantification and identification of opportunities for RET's. Design of solar dryers. Design of solar photovoltaic system. Design of gasifiers for thermal energy and power generation. Design of combuster (gasifier stove). Study of solar greenhouse. Study of biogas engine generator set. Case study of agro-industrial energy estimation and visit to RSE power generation site.

Learning outcome

Students will be acquainted with energy quantification techniques, design of system, economic evaluation and utilization of renewable energy sources for agro-industrial applications.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Elucidation of unit operations in industry.	1
2.	Energy quantification techniques, system boundary,	2
3.	Estimation of productivity, plant capacity utilization,	2
4.	Energy density ratio and energy consumption pattern.	2
5.	Energy flow diagram conservation opportunities identification.	1
6.	Solar energy for industrial application.	1
7.	Solar water heating.	1
8.	Steam solar cooking system.	1
9.	Industrial solar dryer and solar process heat.	2
10.	Solar cooling system (refrigeration, air conditioning and solar architecture technology).	2
11.	Solar furnace.	1
12.	Solar greenhouse technology for high-tech cultivation.	2
13.	Solar photovoltaic technology for industrial power.	1
14.	Bio energy for industrial application	1
15.	Quantification of industrial bio-waste, its characterization	2
16.	Power generation through bio-methanation,	2
17.	Gasification and dendro thermal power plant.	2
18.	Wind energy: Aero generator of new era.	1
19.	National and international state of art in wind power generation.	2
20.	Other renewable energy sources: Magneto hydro dynamics, fuel cells technology and micro-hydro energy technology.	3
	Total	**32**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Elucidation and energy consumption for unit operations in industry.	1
2.	Study of energy quantification and identification of opportunities for RET's	1
3.	Design of solar dryers.	2
4	Design of solar photovoltaic system.	2
5.	Design of gasifiers for thermal energy and power generation.	2
6.	Design of combuster (gasifier stove).	2
7.	Study of solar greenhouse.	1
8.	Study of biogas engine generator set.	1
9.	Case study of agro-industrial energy estimation	2
10.	Visit to RSE power generation site.	1

	Total	**15**

Suggested Reading

- Duffie JA and Beakman WA. 2006. Solar Energy Thermal Process. John Wiley and Sons, New York.
- Kumar S. 2011. Energy Conservation Building User Code Guide. Bureau of Energy Efficiency, New Delhi.
- Rathore NS, Kurchania AK and Panwar NL. 2007. Non-Conventional Energy Sources. Himanshu Publications, Udaipur, Rajasthan.
- Sayigh AAM. 2012. Solar Energy Engineering. Academic Press, New York.
- Singh P, Kurchania AK, Rathore NS and Mathur AN. 2005. Sustainable Development through Renewable Energy Sources. Yash Publications, Bikaner, Rajasthan.

CSE 503 NEURO-FUZZY APPLICATION IN ENGINEERING (2+1)

Aim

To learn the basic concept of neural network models and fuzzy logic based models and apply fuzzy reasoning and fuzzy inference to solve various agricultural engineering problems

Theory

Unit I

Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.

Unit II

Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions. Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T- conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling. Applications of fuzzy reasoning and modelling in engineering problems.

Unit III

Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods. Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks, recurrent networks, hopfield networks, hebbian learning, self organizing networks, unsupervised learning, competitive learning.

Unit IV

Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.

Unit V

Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.

Practicals

Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks. Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees, data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule-based

structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks.

Learning outcome

The students will be able to have the basic concept of neural network models and fuzzy logic-based models and will be in a position to apply fuzzy reasoning and fuzzy inference for various problems of agricultural engineering. They will also learn to develop different types of neural network models.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Basic concepts of neural networks and fuzzy logic, differences between conventional computing and neuro-fuzzy computing, characteristics of neuro-fuzzy computing.	3
2.	Fuzzy set theory: Basic definitions, terminology, formulation and parameters of membership functions.	3
3.	Basic operations of fuzzy sets: Complement, intersection, vision, T-norm and T-conorm. Fuzzy reasoning and fuzzy Inference: Relations, rules, reasoning, Inference systems, and modeling.	4
4.	Applications of fuzzy reasoning and modelling in engineering problems.	3
5.	Fundamental concepts of artificial neural networks: Model of a neuron, activation functions, neural processing. Network architectures, learning methods.	3
6.	Neural network models: Feed forward neural networks, back propagation algorithm, applications of feed forward networks	3
7.	Recurrent networks, hopfield networks, hebbian learning, self-organizing networks, unsupervised learning, competitive learning.	4
8.	Neuro–fuzzy modelling: Neuro-fuzzy inference systems, neuro-fuzzy control.	3
9.	Applications of neuro-fuzzy computing: Time series analysis and modelling, remote sensing, environmental modelling.	4
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Training algorithms of artificial neural networks: Basic models, learning rules, single layer and multi-layer feed-forward and feedback networks, supervised and unsupervised methods of training, recurrent networks, modular networks	5
2.	Fuzzy systems: Fuzzy sets, operations on fuzzy sets, fuzzy relations, measures, fuzzy logic, fuzzy logic controller, integrated hybrid systems. Adaptive neuro-fuzzy inference systems, coactive neuro-fuzzy modelling, classification and regression trees,	5
3.	Data clustering algorithms like k-means, fuzzy c-means, mountain and subtractive clustering, rule based structure identification, neuro-fuzzy control, case studies. Use of available software for fuzzy logic and neural networks	6
	Total	**16**

Suggested Reading

- Jang, JS R, Sun C Tand Mizutan E 1997. Neuro-Fuzzy and Soft Computing. Prentice Hall

- Simon Haykin NJ. 1994. Neural Networks. A Comprehensive Foundation. McMillan College Publishing Company.
- Klir George J and Forger TA. 1995. Fuzzy Sets, Uncertainty and Information. Prentice Hall of India, Pvt. Ltd, New Delhi.
- Kosko B. 1997. Neural Networks and Fuzzy Systems. Prentice Hall of India Pvt. Ltd, New Delhi.
- Rao V and Rao H. 1996. C++ Neural Networks and Fuzzy Logic. BPB Publications, New Delhi.

CSE 506 DIGITAL IMAGE PROCESSING (2+1)

Aim

To give an overview of digital image processing including visual perception, image formation, spatial transformations, image enhancement, color image representation and processing, edge detection, image segmentation and morphological image processing.

Theory

Unit I

Digital image fundamentals, elements of visual perception, light and the electromagnetic spectrum, image sensing and acquisition, image sampling and quantization, basic relationships between pixels, linear and nonlinear operations.

Unit II

Image enhancement in the spatial domain, basic gray level transformations, histogram processing, basics of spatial filtering, smoothing spatial filters, sharpening spatial filters.

Unit III

Color image processing, color fundamentals, color models, pseudo color image processing, basics of full-color image processing, color transformations, smoothing and sharpening, color segmentation.

Unit IV

Image segmentation, detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds.

Unit V

Morphological image processing, dilation and erosion, opening and closing, extensions to gray-scale images.

Practical

To write program to read and display digital image, image processing program using point processing method, program for image arithmetic operations, program for image logical operations, program for histogram calculation and equalization, program for geometric transformation of image, understand various image noise models and to write programs for image restoration and to remove noise using spatial filters. Brief outline of image processing tools.

Learning outcome

This course introduces digital image processing. It focuses on the theory and algorithms underlying a range of tasks including acquisition, formation, enhancement, segmentation and representation.

Lecture Schedule

S. No.	Topics	No. of Lectures

1.	Introduction and Fundamentals, Motivation and Perspective, Applications, Components of Image Processing System,	3
2.	Element of Visual Perception, A Simple Image Model	1
3.	Sampling and Quantization.	2
4.	Light and the electromagnetic spectrum, image sensing and acquisition	2
5.	Basic relationships between pixels, linear and nonlinear operations	2
6.	Image Enhancement in Spatial Domain	2
7.	Introduction; Basic Gray Level Functions	2
8.	Histogram Specification	2
9.	Basics of spatial filtering, smoothing spatial filters, sharpening spatial filters	2
10.	Color image processing, color fundamentals	1
11.	Color models, pseudo color image processing	1
12.	Color transformations, smoothing and sharpening, color segmentation.	2
13.	Image segmentation, detection of discontinuities	1
14.	Edge linking and boundary detection, thresholding, region-based segmentation	2
15.	Segmentation by morphological watersheds	1
16.	Morphological image processing, dilation and erosion	2
17.	Opening and closing, extensions to gray-scale images	2
	Total	**30**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Display digital image, image processing program using point processing method, program for image arithmetic operations	3
2.	Program for image arithmetic operations, image logical operations, histogram calculation and equalization	4
3.	Program for geometric transformation of image, understand various image noise models	4
4.	Programs for image restoration and to remove noise using spatial filters	4
5.	Brief outline of image processing tools	1
	Total	**16**

Suggested Reading

- Jayaraman S, Esakkirajan S and Veerakumar T. Digital Image Processing. Tata McGraw Hill Publication.
- Rafael CG and Richard EW. Digital Image Processing. Third Edition, Pearson Education.
- Sridhar S. Digital Image Processing. Oxford University Press.

CE 501 DIMENSIONAL ANALYSIS AND SIMILITUDE (2+0)

Syllabus attached in Section 4, Page No. 101.

ME 501 MECHATRONICS AND ROBOTIS IN AGRICULTURE (2+0)

Syllabus attached in Section 4, Page No. 87.

ME 507 FATIGUE DESIGN (2+1)

Syllabus attached in Section 4, Page No. 92.

ME 515 COMPUTER AIDED DESIGN (2+1)

Syllabus attached in Section 4, Page No. 93.

IDE 601 RECENT DEVELOPMENTS IN IRRIGATION ENGINEERING (2+1)

Aim

To focus the students for the recent designs progressed in surface irrigation systems, surface and subsurface drip irrigation systems and for utilizing good and poor- quality waters for sustaining crop productivity.

Theory

Unit I

Geospatial analysis of hydraulic properties of the soil. Surge flow irrigation systems. One dimensional and two-dimensional zero inertia modelling of border irrigation, surge irrigation and furrow irrigation. Integral equation solutions to surface irrigation. Design of irrigation runoff recovery systems. Cablegation: Automated supply for surface irrigation. Analyzing wind distortion in sprinkler irrigation systems uniformity.

Unit II

Design of sub-surface drip irrigation systems. Modeling soil water regimes and solute distribution emanating from surface and sub-surface drip irrigation systems. Recent developments in designs of surface and sub-surface drip irrigation systems. Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity. Irrigation scheduling through partial root zone irrigation. Low energy drip irrigation systems.

Unit III

Drip irrigation for poor quality water. Drip automation for time and volume. Drip irrigation system modification for waste water utilization. Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function. Crop water salinity response function.

Unit IV

Drip irrigation in command area development. Mulching and its effect on crop productivity. Analyzing moisture and temperature profiles with time and depth. Effect of shading and mulching on crop productivity, vapour phase movement.

Practical

Designing border irrigation using zero inertia model, volume balance approaches, evaluating surge flow irrigation systems, operation of segmented border irrigation systems for enhancing water use efficiency, geospatial analysis of soil properties, design and planning of surface drip irrigation systems using various designs, design subsurface drip irrigation, analyzing three dimensional moisture movement under subsurface drip irrigation using simple empirical models, design and planning of surface and subsurface drainage systems, developing the irrigation schedules using partial root zone irrigation, seasonal and dated production functions for forecasting crop yield

Learning outcome

The students will be able to design, operate and maintain surface irrigation systems, surface and sub-surface pressurized irrigation systems and managing crop productivity with poor quality of waters without deteriorating soil conditions.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Geospatial analysis of hydraulic properties of soil: Geospatial analysis, Spatial interpolation, Data quality assessment, Vegetation analysis, Correlation analysis	3
2.	Surge flow: Effect of surging on infiltration and surface flow hydraulics, surge flow systems	2
3.	Zero inertia modeling of border irrigation	2
4.	Integral equation solutions to surface irrigation: Border and furrow irrigation method	2
5.	Design of irrigation runoff recovery systems: Border and furrow irrigation method	3
6.	Cablegation: Automated supply for surface irrigation	2
7.	Wind effects on sprinkler irrigation performance: Analyzing wind distortion in sprinkler irrigation system uniformity	2
8.	Design of sub-surface drip irrigation systems, Modeling soil water regimes and solute distribution emanating from sub-surface drip irrigation systems	3
9.	Effects of emitter variability and plant and soil variability on soil moisture distribution uniformity	2
10.	Irrigation scheduling through partial root zone irrigation.	2
11.	Low energy drip irrigation systems	2
12.	Drip irrigation for poor quality water, Drip automation for time and volume, Drip irrigation system modification for waste water utilization	2
13.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function, Crop water salinity response function	3
14.	Drip irrigation in command area development	2
15.	Mulching and its effect on crop productivity, Analyzing moisture and temperature profiles with time and depth, Effect of shading and mulching on crop productivity, vapour phase movement	3
	Total	**35**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Study of geospatial analysis of soil properties	1
2.	Design of border irrigation using zero inertia model	1
3.	Design of border irrigation using volume balance approach	1
4.	Design and evaluation of surge flow irrigation system	1
5.	Design of irrigation runoff recovery system for border irrigation method	1
6.	Design of irrigation runoff recovery system for furrow irrigation method	1
7.	Design and planning of cablegation system	1
8.	Analysis of wind distortion in sprinkler irrigation system uniformity	1
9.	Design and planning of subsurface drip irrigation system	1
10.	Analysis of three dimensional moisture movement under subsurface drip irrigation using simple empirical models	2
11.	Development of irrigation schedules using partial root zone irrigation	1
12.	Modeling deficit irrigation and crop yield in response to hydraulic variation of the system and distribution uniformity of the soil-crop water fertilizer response function	1
13.	Analysis of moisture and temperature profiles with time and depth	1

14.	Development of seasonal and dated production functions for forecasting crop yield of irrigation runoff recovery system for furrow irrigation method	1
	Total	**15**

Suggested Reading

- Cuenca RH. 1989. Irrigation System Design: An Engineering Approach. Prentice Hall, New York.
- Hoffman GJ, Evans RG, Jensen ME, Martin DL and Elliot RL. (ed). 2007. Design and
- Operation of Farm Irrigation Systems. American Society of Agricultural Engineers St. Joseph Michigan.
- James LG. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York, USA.
- Nakayama FS and Bucks DA. 1986. Trickle Irrigation for Crop Production: Design, Operation and Management. Elsevier Publications, Amsterdam.
- Skogerboe GV and Walkar WR. 2008. Surface Irrigation Theory and Practice. Prentice Hall, New York.

IDE 602 ADVANCES IN DRAINAGE ENGINEERING (2+1)

Aim

To provide comprehensive knowledge of advances in land drainage, synthetic materials for drainage systems, linear flow laws and environmental issues related to drainage.

Theory

Unit I

Physics of land drainage. Forces, surface tension and energy effects water. Energy of soil water. Capillary potential.

Unit II

Devices to measure capillary potential. Hystersis, Darcy's law. Synthetic materials for drainage systems. Environmental issues related to drainage. Socio-economic impacts of drainage systems.

Unit III

Laplace equation its derivation and solution in various forms. Boundary value problems, Liner flow laws.

UNIT IV

Drainage criteria saturated flow theory, steady flow and non steady flow. Controlled drainage for reducing agricultural non-point pollution. Application of simulation models for drainage systems.

Unit V

Flow equations in general and the approach. Flow problem and physical boundary conditions.

Practical

Steady state and non steady state flow problems. Measurement of capillary potential. Use of various synthetic materials under the field condition. Use of simulated models for drainage system.

Learning outcome

The student will be familiar about energy of soil water, capillary potential, drainage material and various sources of agricultural pollution and also able to develop and apply simulation model for management of drainage system for particular area.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Physics of land drainage: Forces acting on movement of water through soil profile, surface tension, capillary forces and energy effects movement of water, Energy of soil water	5
2.	Capillary potential: Effect of capillary potential on movement of water through porous media, devices to measure capillary potential. Hystersis effect in drainage of soil, Darcy's law	3
3.	Synthetic materials for drainage systems: Design of filter and envelop for drainage system with synthetic materials	2
4.	Environmental issues related to drainage. Socio-economic impacts of drainage systems	2
5.	Drainage Flow Equation: Laplace equation its derivation and solution in various forms, Liner flow laws	4
6.	Boundary value problems: Initial and boundary condition and its solution	3
7.	Drainage criteria: Drainage criteria for different type of soils and crops, guidelines for design and installation of drainage system	2
8.	Saturated flow theory: steady flow and non steady saturated flow	3
9.	Controlled drainage for raising crop and reducing agricultural non-point pollution	2
10.	Application of simulation models for drainage systems (DRAINMOD, SALTMOD, etc)	4
11.	Flow equations: general drainage flow equations and the approach, drainage flow problems and solutions with physical boundary conditions	3
	Total	**34**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Steady state drainage flow problems	3
2.	Unsteady state drainage flow problems	3
3.	Measurement of capillary potential	2
4.	Use of various synthetic materials for drainage filter under the field condition	2
5.	Design of filter and envelop with synthetic materials	2
6.	Use of simulated models for drainage system	4
	Total	**16**

Suggested Reading

- Chauhan HS. 1999. Mathematical Modeling of Agricultural Drainage, Ground Water and Seepage. ICAR Publication New Delhi.
- Kirkham DL and Powers WL. 1972. Advanced Soil Physics. Inter Science, New York.
- Lambert K Smedema, Willem FV, Lotman and David Rycroft. 2004. Modern Land Drainage: Planning, Design and Management of Agricultural Drainage Systems. CRC Press.
- Ritzema HP. (Ed.). 1994. Drainage Principles and Applications. ILRI.
- Skaggs RW and Schilfgaarde Jan Van. 1999. Agriculture Drainage. Monograph No. 17. American Society of Agronomy Madison, Wisconsin, USA.

IDE 603 HYDRO-MECHANICS AND GROUNDWATER MODELING (3+0)

Aim

To acquaint students about the concept of soil aquifer system, unsaturated flow models, numerical modeling of groundwater flow, theory of krigging and movement of groundwater in fractured and swelling porous media.

Theory

Unit I

Concept of soil aquifer system, flow of water in partially saturated soils. Partial differential equation of flow, pressure under curved water films, moisture characteristic functions.

Unit II

Physical models, Analog models, Mathematical modelling, Unsaturated flow models, Numerical modelling of groundwater flow, Finite difference equations and solutions. Successive over relaxation. Alternating direction implicit procedure. Crank Nicolson equation. Iterative methods. Direct methods. Inverse problem. Finite element method.

Unit III

Determination of unsaturated hydraulic conductivity and model for its estimation. Diffusivity and its measurement. Infiltration and exfiltration from soils in absence and presence of water table.

Unit IV

Fence diagram and aquifer mapping. Movement of groundwater in fractured and swelling porous media. Spatial variability, theory of krigging.

Unit V

Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions. Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation. Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction.

Learning outcome

The students will be able to understand complex mechanics movement of water in soil systems and also able to estimate the statistical parameters for better understanding of soil aquifer system, model validation and prediction.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Concept of soil aquifer system	1
2.	Flow of water in partially saturated soils	1
3.	Partial differential equation of flow	1
4.	pressure under curved water films, moisture characteristic functions	1
5.	Different types of Models used in hydrology and Groundwater	1
6.	Unsaturated flow models	1
7.	Numerical modelling of groundwater flow	1
8.	Finite difference equations and solutions, Finite difference equations and solutions, Alternating direction implicit procedure	4
9.	Crank Nicolson equation. Iterative methods	2
10.	Inverse problem. Finite element method	1

11.	Determination of unsaturated hydraulic conductivity and model for its estimation	2
12.	Diffusivity and its measurement	1
13.	Infiltration and exfiltration from soils in absence and presence of water table 2	2
14.	Fence diagram and aquifer mapping	2
15.	Movement of groundwater in fractured and swelling porous media, Spatial variability, theory of krigging	4
16.	Data requirements. Conceptual model design: Conceptualization of aquifer system. Parameters, Input-output stresses, Initial and Boundary conditions	4
17.	Model design and execution: Grid design, Setting boundaries, Time discretization and transient simulation	4
18.	Model calibration: Steady state and unsteady state. Sensitivity analysis. Model validation and prediction. Uncertainty in the model prediction	6
19.	Course Seminar	4
	Total	**43**

Suggested Reading

- Anderson MP and Woessner WW. 1992. Applied Groundwater Modelling: Simulation of Flow and Advective Transport. Academic Press, Inc.
- Elango L and Jayakumar R. 2001. Modelling in Hydrology. Allied Publishers Ltd.
- Fetter CW. 1999. Contaminant Hydrogeology. Prentice Hall.
- Kirkham and Powers. 1972. Advanced Soil Physics. John Wiley & Sons.
- Muskat M. 1937. The Flow of Homogeneous Fluid through Porous Media. McGraw Hill.
- Rushton KR. 2003.Groundwater Hydrology: Conceptual and Computational Models. Wiley,

IDE 604 SOIL-WATER-PLANT-ATMOSPHERIC MODELING (2+1)

Aim

To impart the knowledge of measurement of radiation within plant cover, thermodynamics of flow through plant cells, heat transfer and radiation eXchange under plant cover.

Theory

Unit I

Radiation balance of earth's surface. Turbulent transport of heat and momentum. Radiation eXchange and heat transfer in a low plant cover.

Unit II

Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover. Predicting potential evapotranspiration.

Unit III

Thermodynamics of flow through plant cells. Dynamics of water movement through soil plant atmosphere system. Stomatal aperture, photosynthesis and actual evapotranspiration relationship.

Unit IV

Production functions of evapotranspiration. Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture.

Unit V

Crop water requirement under protected cultivation and remote sensing-based modeling.

Practical

Estimation of potential evapotranspiration. Measurement of ET parameters under open and protected cultivation and development of stochastic and deterministic models of ET. Use of software for estimation of crop water requirement and ET.

Learning outcome

The students will be able to understand the measurement of radiation, photosynthesis and actual evapotranspiration relationship along with modeling of evapotranspiration.

Lecture Schedule

S. No.	Topics	No. of Lectures
1.	Radiation balance of earth's surface	1
2.	Turbulent transport of heat and momentum	2
3.	Radiation exchange and heat transfer in a low plant cover	2
4.	Measurement of radiation, leaf and air temperature, humidity and wind profiles within plant cover	2
5.	Predicting potential evapotranspiration	2
6.	Thermodynamics of flow through plant cells	2
7.	Dynamics of water movement through soil plant atmosphere system	2
8.	Stomatal aperture, photosynthesis and actual evapotranspiration relationship	1
9.	Production functions of evapotranspiration	3
10.	Evapo-transpiration in mathematical modelling and optimization of design and regulation of irrigation systems and for utilization of limited water resources in agriculture	4
11.	Crop water requirement under protected cultivation and remote sensing-based modeling	4
	Total	**29**

List of Practicals

S. No.	Topics	No. of Lectures
1.	Estimation of potential evapotranspiration using FAO 56 Penman Monteith equation	1
2.	Estimation of potential evapotranspiration using FAO Cropwat model	1
3.	Estimation of potential evapotranspiration using FAO ETo calculator	2
4.	Measurement of ET parameters under open condition	1
5.	Measurement of ET parameters under protected cultivation	1
6.	Development of stochastic models of ET	3
7.	Development of deterministic models of ET	3
8.	Use of software for estimation of crop water requirement and ET	2
	Total	**14**

Suggested Reading

- Amarjit Basra. 1994. Mechanisms of Plant Growth and Improved Productivity. CRC Press New York.
- Daniel Hillel. Advances in Irrigation. All Volumes.

- Nieder AR and Benbi D. 2003. Handbook of Processes and Modeling in the Soil-Plant System. CRC Press New York.
- Peter J Gregory. Plant Roots, their Growth Activity and Interaction with Soils. Wiley Blackwell New York.

IDE 606 MULTI CRITERIA DECISION MAKING SYSTEMS (2+0)

Aim

To acquaint students about multi criteria decision making system which include multi-attribute decision making and multi-objective decision making.

Theory

Unit I

Introduction: MCDM overview, basic foundations and Pareto optimality elementary decision analysis. Decision trees and influence diagrams.

Unit II

Multi–attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition, Multi–facility location analysis, eXpected utility theory, single attribute utility functions, multi–attribute overview, two–attribute utility models, multi–attribute computer programs, multi–attribute assessment.

Unit III

Multi-objective decision making (MODM): Vector optimization theory, weighting methods, weighting example. Linear vector optimization (LVOP), parametric decomposition, LVOP algorithm, LVOP example.

Unit IV

Non interactive and interactive methods: Geoffrion's Bi-criterion method, linear goal programming, nonlinear and integer goal programming.

Unit V

Interactive trade-off methods: Zionts–Wallenius, Surrogate worth, Group decision making methods.

Learning outcome

The students will be able to understand and learn to apply various techniques for the best solutions of real-life command area and other hydrological problems.

List of Practicals

S. No.	Topics	No. of Lectures
1.	MCDM overview	1
2.	Basic foundations and Pareto optimality elementary decision analysis	2
3.	Decision trees and influence diagrams	1
4.	Multi-attribute decision making (MADM): Deterministic utility theory, value decomposition, additive value decomposition	2
5.	Multi-facility location analysis	1
6.	Expected utility theory	1
7.	Single attribute utility functions	1
8.	Multi-attribute overview	1
9.	Two-attribute utility models	1
10.	Multi-attribute computer programs and multi–attribute assessment	2

11.	Multi-objective decision making (MODM)	1
12.	Vector optimization theory	1
13.	Weighting methods and examples related with weighting	2
14.	Linear vector optimization (LVOP)	1
15.	Parametric decomposition	2
16.	LVOP algorithm and LVOP example	2
17.	Non interactive and interactive methods	2
18.	Geoffrion's Bi-criterion method	1
19.	Linear goal programming, nonlinear and integer goal programming	2
20.	Interactive trade-off methods	1
21.	Zionts-Wallenius and Surrogate worth	2
22.	Group decision making methods	2
	Total	**32**

Suggested Reading

- Cohon JL. 2004. Multiobjective Programming and Planning. Dover Publications.
- Doumpos M and Grigoroudis E. 2013. Multicriteria Decision Aid and Artificial Intelligence: Links, Theory and Applications. Wiley-Blackwell.
- Figueira J, Greco S and Ehrgott M 2007. Multiple Criteria Decision Analysis: State of the Art Surveys. Springer.
- Tzeng GH and Huang JJ. 2011. Multiple Attribute Decision Making: Methods and Applications. Chapman and Hall/CRC.
- Tzeng GH and Huang JJ. 2013. Fuzzy Multiple Objective Decision Making. Chapman and Hall/CRC.

11. Supporting Courses

CPE-RPE RESEARCH PUBLICATION AND ETHICS (1+1)

Course structure

The course comprises of six modules listed in table below. Each module has 4-5units.

Modules	Unit title	Teaching hours
	Theory	
RPE 01	Philosophy and Ethics	4
RPE 02	Scientific Conduct	4
RPE 03	Publication Ethics	7
	Practice	
RPE 04	Open Access Publishing	4
RPE 05	Publication Misconduct	4
RPE 06	Databases and Research Metrics	7
	Total	**30**

Syllabus in detail

Theory

RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements andreactions.

RPE 02: SCIENTIFIC CONDUCT (5 hrs.)

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salamislicing
5. Selective reporting and misrepresentation of data

RPE 03: PUBLICATION ETHICS (7 hrs.)

1. Publication ethics: definition, introduction and importance
2. Best practices/ standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethicalbehaviour and vice versa, types.
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

Practice

RPE 04: OPEN ACCESS PUBLISHING (4 hrs.)

1. Open access publication and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self – archiving policies.
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder/ Journal suggestion tools viz. JANE, Elsevier Journal Finder,Springer

RPE 05: PUBLICATION MISCONDUCT (4 hrs.)

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflits of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software Tools (2 hrs.)

1. Use of plagiarism software like Turnitin, Urkund and other open-source software tools.

RPE 06: DATABASES AND RESEARCH METRICS (7 hrs.)

A. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics.

References

- Bird, A. (2006) Philosophy of Science, Routledge.
- MacIntyre, Alasdair (1967) A Short History of Ethics, London.
- P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 978-9387480865
- National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition.

National Academic Press.
- Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
- Bcall, J. (2012). Predatory publishers are corrupting open access. Nature, 489 (7415), 179-179.
- https:// doi.org/10.1038/489179a
- Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN: 978-81-939482-1-7
- http://www.insaindia.rcs.in/pdf/Ethics_Bookj.pdf

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